ENGINEERING NEWS

A JOURNAL OF CIVIL, MECHANICAL, MINING AND ELECTRICAL ENGINEERING

Vol. 64. No. 23. 220 Broadway, New York, December 8, 1910.

TABLE OF CONTENTS.

LEADING ARTICLES:	Page.
Movable Dams on the New York State Barge Canal (illustrated)	611
Elements of a Constructive Franchise Policy; Delos F. Wilcox	613
A Rock-Transporting Cableway for the Harbor Works of Rangoon, Burmah (illustrated)	618
Engineering Testimony in Court Actions; G. B. Zahniser	619
Analysis of Velocity Rates of Epicyclic Gear Trains (illustrated); A. Lewis Jenkins	620
The Clinkering of Coal: Results of Tests for Effect of Various Constituents in the Ash (illustrated); Lionel S. Marks, M. Am. Soc. M. E.	623
Some Tests of Old Timber; C. P. Buchanan	627
The Development of the Municipal Water-Works of Spokane, Wash., and the Addition of an Electric Pumping Station (illustrated); Alexander J. Lindsay	628
Corrosion of Hot Water Piping in Bath Houses; Ira H. Woolson	630
Total Excavation and Concrete Laying on Panama Canal through October, 1910	633
Sterilization of Polluted Water by Ultra-Violet Rays at Marseilles, France (illustrated)	633
Conveying and Depositing Concrete by Gravity Chutes (illustrated)	634
The Collapse of the Reinforced-Concrete Henke Building, Cleveland, Ohio (illustrated)	636
Disposal of Trade Wastes; George A. Johnson, Assoc. M. Am. Soc. C. E.	637
The Substitution of Electric Traction for Steam in the Boston Metropolitan District (illustrated)	638
Opening of the Michigan Central Ry. Tunnel under the Detroit River	640
EDITORIAL	631
A Remarkable Term of Service for an Engineer—The Strength of Old Timbers—A High Boiler Efficiency Record and Its Analysis—The Interference of Public Utilities with Each Other.	
The Steam Jet as a Means of Preventing Clinker in Boiler Furnaces	632
LETTERS TO THE EDITOR	632
Economic Comparison of Railway Tie Material; Neil N. Campbell—Good Street Paving as a Promoter of Public Morals; F. W. D.—Transition Curves by Slide-Rule; E. R. Cary.	
ENGINEERING NEWS OF THE WEEK	641
PERSONALS	642
ENGINEERING SOCIETIES	642

Movable Dams on the New York State Barge Canal.

The New York State Barge Canal in the section from Rome east nearly to the Hudson, is to be operated mainly in slack-water navigation in the Mohawk, a river subjected to floods from its numerous tributaries. On account of these floods and of the ice-jams in the spring, to close the river at the various locations where change of water level is necessary would subject the structures there to an excessive strain and wear and would also flood many acres of good farming land above each of the dams. It was therefore decided to build at each lock a movable dam which could be kept closed during the navigation season and which would be opened during the winter or at any time when the flood waters threatened damage to surrounding land and structures. In the section between Little Falls and Schenectady there are eight of these movable dams, all of the same type, although of somewhat different dimensions.

The type of dam adopted is known as the bridge dam with the Boulé gates. It consists of a series of ordinary bridge trusses, upon concrete piers, carrying, hinged from the down-stream lower chord, a series of steel frames which swing down into the river, and there butt against concrete and cast-iron blocks embedded in the river bottom. On these frames are lowered two sets of gates, an upper and a lower, to control high or low flow as needed. The gates are controlled by a small hoist that travels across the bridge floor and raises or lowers the gates as desired.

The dams shown here are No. 6 at Cranesville (Figs. 1, 14) and No. 7 at Amsterdam (Figs. 2-13).

As is shown in Fig. 2, the dam at Amsterdam consists of a middle span of 216 ft. flanked on either side by a span of 186 ft., with a small span across the lock on the north side of the river. Each of the three main spans is made up of two curved-upper-chord riveted Pratt trusses of the intermediate vertical type, carrying at each post heavy floor-beams from the down-stream end of which are hung the frameworks carrying the dam gates. On account of the eccentric loading upon the spans due to the water-pressure reaction at the far down-stream end of the floor-beams, the stresss on the two trusses of each span are entirely different, although the outlines of the trusses are identical.

Referring to the section through the dam in Fig. 2 it will be seen that when the dam is open the hanger beams are held up under the floor-beams with their load about equally distributed between the two trusses but with the load of the gates bringing the heavier reaction on the down-stream truss. When the dam is to be closed, the hanger framework is first lowered by means of the chains attached to the up-stream end of the floor-beam. During this operation there is evidently a load on both ends of the floor-beams, from the hanger framework proper and from the lowering chains. The hanger once down, the weight is all carried through its hinge to the down-stream end of the floor-beam and the chain slacked off, no weight being carried to the bottom. The gates are then lowered and their weight relieved from the floor-beam, which then takes, through its down-stream end, the horizontal upper reaction from the water pressure, the lower reaction being taken by the butting blocks in the river.

It is thus seen that there is quite a variation in the loads on the structure, which results in different stresses in the trusses as well as a different make-up. In Fig. 3 are shown the stresses in the 216-ft. trusses as well as in the lower lateral system.

It is assumed that all of the water-pressure load is carried in the plane of the lower chord, throught the chords, floor-beams and heavy lower lateral system. The upper lateral system consists merely of transverse struts at the top of the main diagonals (at every other panel point) with light X-bracing between. There is no sway-bracing and only a transverse strut for portal bracing.

The floor-beams are in two general types, the intermediate floor-beam carrying the hanger beams and gates that form the dam, and the

FIG. 1. VIEW OF DAM 6 AT CRANESVILLE, N. Y., IN COURSE OF CONSTRUCTION.

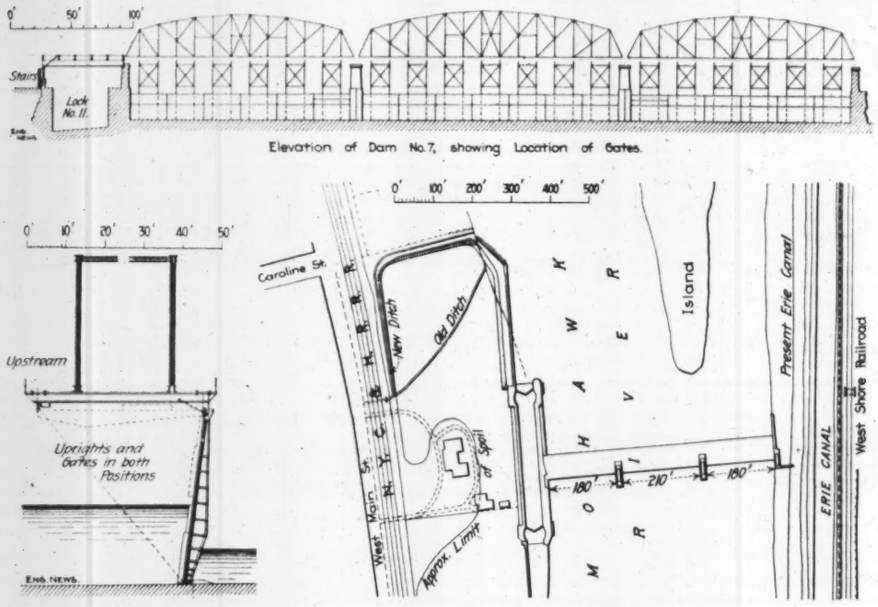


FIG. 2. GENERAL PLAN, OUTLINE ELEVATION AND SECTION OF DAM 7, NEW YORK STATE BARGE CANAL.

end floor-beams, one at each end of each truss, which do not carry hangers but which are complicated by the connection to the bridge seat and shoe. All of the beams are suspended below the posts by riveted connections, as shown in Fig. 4.

Fig. 8 shows the details of a typical intermediate floor-beam. It is suspended from the posts of the truss at the regular 24-ft. spacing and overhangs on the up-stream side 13 ft. 3 ins. and on the down-stream side 11 ft. 7 ins. Its depth is a uniform 28¼ ins. but owing to requirements of space for the lifting chains and also of strength, the section is materially changed throughout its length as the plan in Fig. 8 will show. Between the down-stream post and the up-stream end the floor-beam is of the single-web plate-girder type, but the up-stream overhang is a double-web girder latticed horizontally.

At the down-stream end of the floor-beam is shown the detail that carries the hanger beams. It consists primarily of six ¼-in. plates, spaced in two groups of three with a clearance of 3¾ ins. between inside plates, and suspended by a riveted connection to the main web of the floor-beam above. At the bottom of the plate is a pin-hole through which is pinned the hanger beam that carries the gates and to take up the reaction from this hanger beam, this lower pin is tied back to the floor-beam near the down-stream post by two 2½ × ¾-in. eye-bars. At the upper end of these eye-bars the web of the floor-beam is strengthened by diaphragms and plates. The gates on the hanger beams are raised and lowered by chains which pass through the floor-beam and are kept while not in use in boxes provided for that purpose. The detail of the chain boxes and locks are described further on in this article.

At the up-stream end of the floor-beam there is another plate hanger carrying an idler sheave over which passes the chain from the post of the hanger beams. At this point there are also chain boxes and locks.

As shown on the drawings, there is no provision for any highway across the bridge except holes for future connections, but such a highway could be built when necessary in the space between the two trusses. On the overhanging sections of the beams is built a 2-in. timber flooring and a track upon which the lifting winches travel.

As the trusses are subjected to a force in line of the stream, a condition not present in the ordinary bridge truss, the detailing of the bridge seats is considerably different than in ordinary bridge trusses. Fig. 5 shows the general design of the fixed and expansion end of each truss and Fig. 7 shows the details of these seats. In general the end of each truss is carried on an end floor-beam which in turn rests on a pin or roller shoe. At the fixed end of the truss this shoe is fastened with a pin connection to an ordinary built-up seat and the reaction due to the force of the water on the gates of the dam is carried through a built-up member, fastened to the base of the floor-beam, to another built-up member embedded in the concrete of the pier. [illegible] detail is shown on Fig. 7. At the ex[illegible] end rollers are interposed between the sh[illegible] d the seat and the horizontal reaction is car[illegible] rom a member fastened to the base of the [illegible] beam near the down-stream truss forward [illegible] other embedded built-up member designed [illegible] y as is the one in the fixed end. The [illegible] ided member and the one fastened to the [illegible] beam are connected by four horizontally p[illegible] eye-bars, which are pinned at either end [illegible] s al-lowing expansion longitudinally to the [illegible] ge at the same time holding the truss secur[illegible] ainst any up or down-stream motion due to [illegible] pres-sure of the water on the dam.

The hangers, which form the dam, are [illegible] anged in pairs from adjacent panel points, as [illegible] shown in the outline drawing, Fig. 2. Each [illegible] anger beam is a plate girder, shown in Fig. 9, [illegible] 1 ft. 6 ins. long, with straight face on the u[illegible] tream side and a curved down-stream face so a[illegible] o pro-vide a varying depth to care for the water pressure. In section it is a single-web girder with the down-stream flange of the ordinary out-turned angle construction and with the up-stream flange of a 10-in. channel arranged with flanges parallel to the web of the girder and forming the track in which the gate rollers travel.

The beam is provided at the top with a slotted hole engaging the pin in the bottom of the hanger attached to the intermediate floor-beams. These slotted holes are provided so that, should drift or ice collect against uprights and prevent raising in regular way, they can be lifted vertically and free of shoe at the bottom, permitting them to swing freely down-stream; probably sufficiently to let the drift pass. The uprights may thus be saved. If not, the pin at top can be withdrawn, casting all loose and saving the bridge. The beams in each pair are tied together with X-

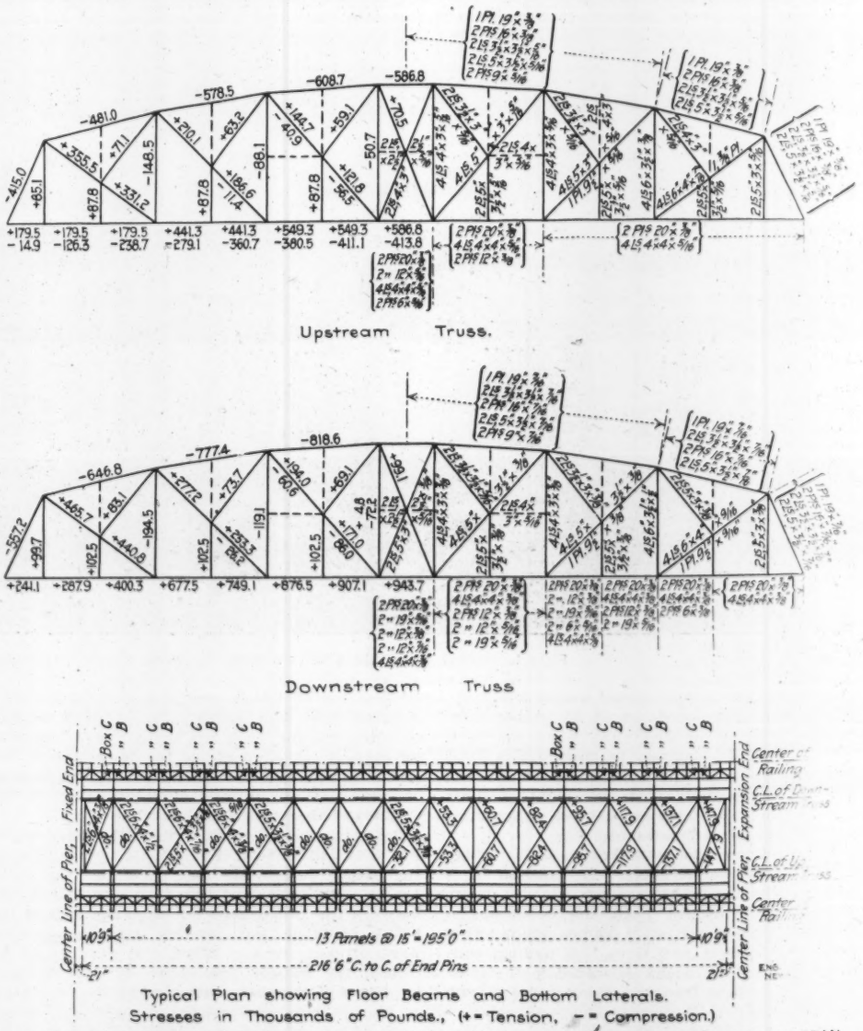

Upstream Truss.
Downstream Truss
Box C
Fixed End
Expansion End
Center Line of Pier
Center of Railing
C.L. of Down Stream Truss
C.L. of Up Stream Truss
13 Panels @ 15'-0" = 195'-0"
21'-6" C. to C. of End Pins
Typical Plan showing Floor Beams and Bottom Laterals.
Stresses in Thousands of Pounds., (+ = Tension, − = Compression.)

FIG. 3. STRESS SHEET AND MAKE-UP OF DOWNSTREAM AND UPSTREAM TRUSSES, 216-FT. SPAN.

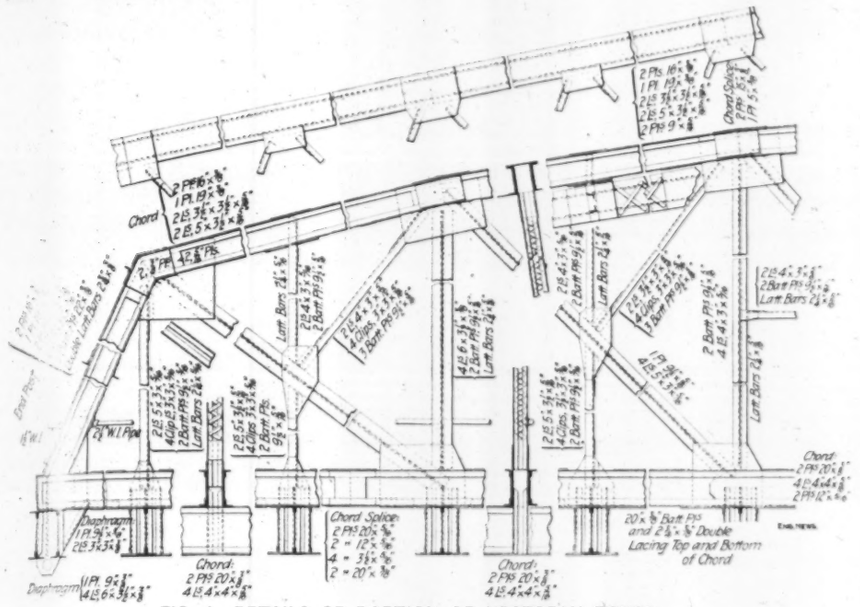
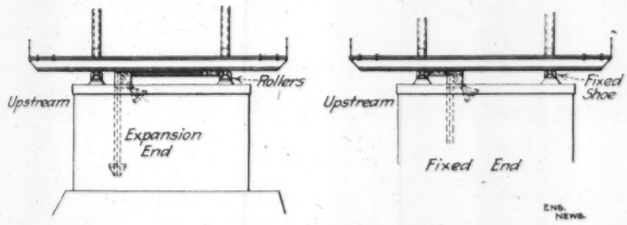


FIG. 4. DETAILS OF PORTION OF UPSTREAM TRUSS.

bracing in pairs, thus forming units, carrying the curtains, which can be raised or lowered separately. At the lower end the hanger is provided with a horizontal pin to which is attached the chain that goes over the idler at the upstream end of the floor-beam and is used to raise or lower the hanger. It should be noted that the chains which control the gates are entirely separate from this chain which lifts the hanger proper. At its lower end, each hanger butts against a cast-iron block (to be described later) embedded in the concrete placed in the bottom of the river. Against the face of the hanger is bolted a small cast-iron block which is faced so as to provide even bearing against the embedded shoes.

Fig. 2 shows the outline location of the various gates. Each pair of hanger beams forms a unit, as noted above, extending over the 15 ft. panel distance. Each one of these units carries



Floor Beam and Anchorage.

FIG. 5. OUTLINE DIAGRAM OF BRIDGE SEATS AND EXPANSION JOINT DEVICE.

at its bottom a set of gates nearly 30 ft. wide which overhang on either side of the hanger unit half a panel length, thus affording a continuous dam from one pier to the other.

As shown in the outline elevation in Fig. 2, all of the gates with two minor variations, are of two types, the upper and the lower. The lower gates shut off the lower 12 ft. of water and the upper one is to be added when a full pool level is required. The details of the two are shown on Fig. 10.

The lower gate consists of three horizontal I-beams and one channel, varying in size according to water pressure, connected by vertical double I-beams and covered on the up-stream face with a skin of ⅜-in. buckled plates. The framework proper is only 29 ft. 8 ins. wide so that there would be an opening of some 4 ins. between adjoining gates were there not provided the hinged cover plate shown at the right of the elevation of gate "A." This plate is hinged to the buckled-plate skin of the gate and will swing in to cover the aperture when the gates are lowered, being forced and held there by the water pressure. A latch is provided near the top of the gate (see Fig. 10) which holds the hinged plate back until it is desired to shut the opening. At the bottom of the gate the steel work reaches to within about 10 ins. of the concrete bottom which has been placed below the dam and the opening is closed by a hanging rigid steel plate and wood timber, which fits down closely against the bottom.

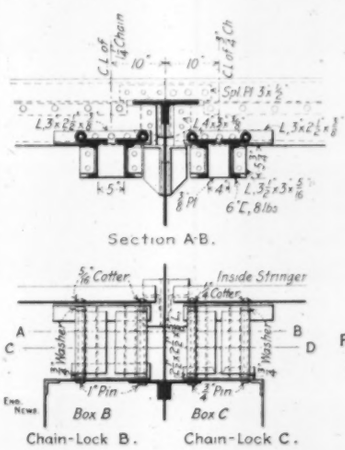
These gates are lifted by chains, attached to the top of the skin and carried up through the floor beams to a winch which travels around the track on the overhanging floor. It will be noticed that the double I-beams forming the vertical members in the gate framework are just 15 ft. apart and are placed exactly opposite the inverted channel track on the up-stream face of the hanger beam. Between these double I-beams are hung on Tobin bronze cotter-pins, as shown in detail on Fig. 10, six cast iron wheels, projecting 3 ins. beyond the inside face of the I-beams. On these wheels as rollers the gates travel, with the wheels bearing against the channel of the hanger. Attached to each of the intermediate horizontal I-beams of the gate framework is a plate bent in Z-bar shape which overlaps the channel of the hanger beam and prevents the wind from blowing the gate away from the hanger when the water pressure is removed. At the piers the construction of the gate to make a close joint is special. On Fig. 11 it will be noted that there is a groove on the face of each pier protected by a steel angle. This groove has a slot of 1 ft. horizontal to 8 vertical, the same as the batter of the dam curtains and goes opposite to the face of the adjacent curtain. A clearance of 4 ins. is provided between the gates and a clearance of 2 ins. between the end gates and the adjacent masonry. A similar plate to the hinged plate noted above will close the opening between the gate and the pier by resting on the groove in the pier end.

Gate "B" is shown also on Fig. 10. It is the same in its details as "A" but is lighter on account of the reduced water pressure. It will be noticed that the chains are in different locations from those on "A," so that there will be no interference in the raising. Closing plates have not been provided for the upper gates, but if necessary, openings may be closed with timbers let down for that purpose.

The chains which are to raise the curtains are of 1¾ to 2-in. wrought-iron for the lower curtains and ¾-in. for the upper ones. They are carried up through the floor-beam and kept in the boxes shown on the right in Fig. 8. When not being moved they are kept taut by special fastenings; one of which is shown in the detail on Fig. . This consists merely of two hinged plates hung on cotter pins which, when closed, are just 1½-in. apart for the 1¼-in. chain and 1-in. apart for the ¾-in. chains. When the lifting operation is going on the hinges are pulled open automatically and there is enough room for the chains to pass freely, but when they are dropped they grip the links securely so they cannot run through. A similar lock is provided at the up-stream end of the floor beam, where the chain operates that lifts the hanger itself.

The gate chains are so attached with reference to the center of gravity of gates that all wheels are in contact with track when hanging free. The gates in place now at Dam 6 (Fig. 1) hang this way exactly as planned. The water pressure, of course, hugs the gates tighter. The wheels will have track only when there is no water and wind of considerable force on back. The plate, bent like Z's, are provided to hold gates when this unusual condition occurs.

Each dam will have two steam winches, self-propelling and interchangeable. The two tracks are connected by semi-circular tracks at each end of dam, so that one winch can do all the work required. Two winches are used for the reserve of the second in case the first breaks down. Steam is considered most dependable and is used for that reason.



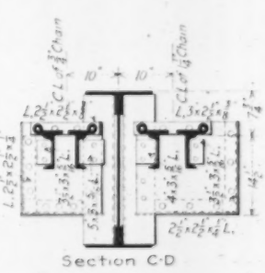


FIG. 6. DETAILS OF CHAIN BOXES AT DOWNSTREAM END OF FLOOR BEAM.

Fig. 11 shows the details of the concrete piers for the bridge dam. Each pier is a simple pedestal construction, with battered cut-waters on both up-stream and down-stream ends, founded on a spread footing in the gravel bottom of the river. Simple reinforcing is added as shown. The groove into which the curtains fit will be noted. Extending out 7 ft. on either side of each pier and for a depth of 5½-ft. below the main pier bottom is a cut-off wall, which is grooved at the end to fit into a similar cut-off wall in the solid paving across the river.

This paving on the bottom of the river is shown in Fig. 13. It consists of irregularly shaped reinforced-concrete paving varying in depth from 2½ to 14 ft., extending across the river for a distance 62½ ft. below the center line of the bridge. Above and below for some 30 ft. farther the bottom is rip-rapped. In this concrete paving the butting blocks detailed in

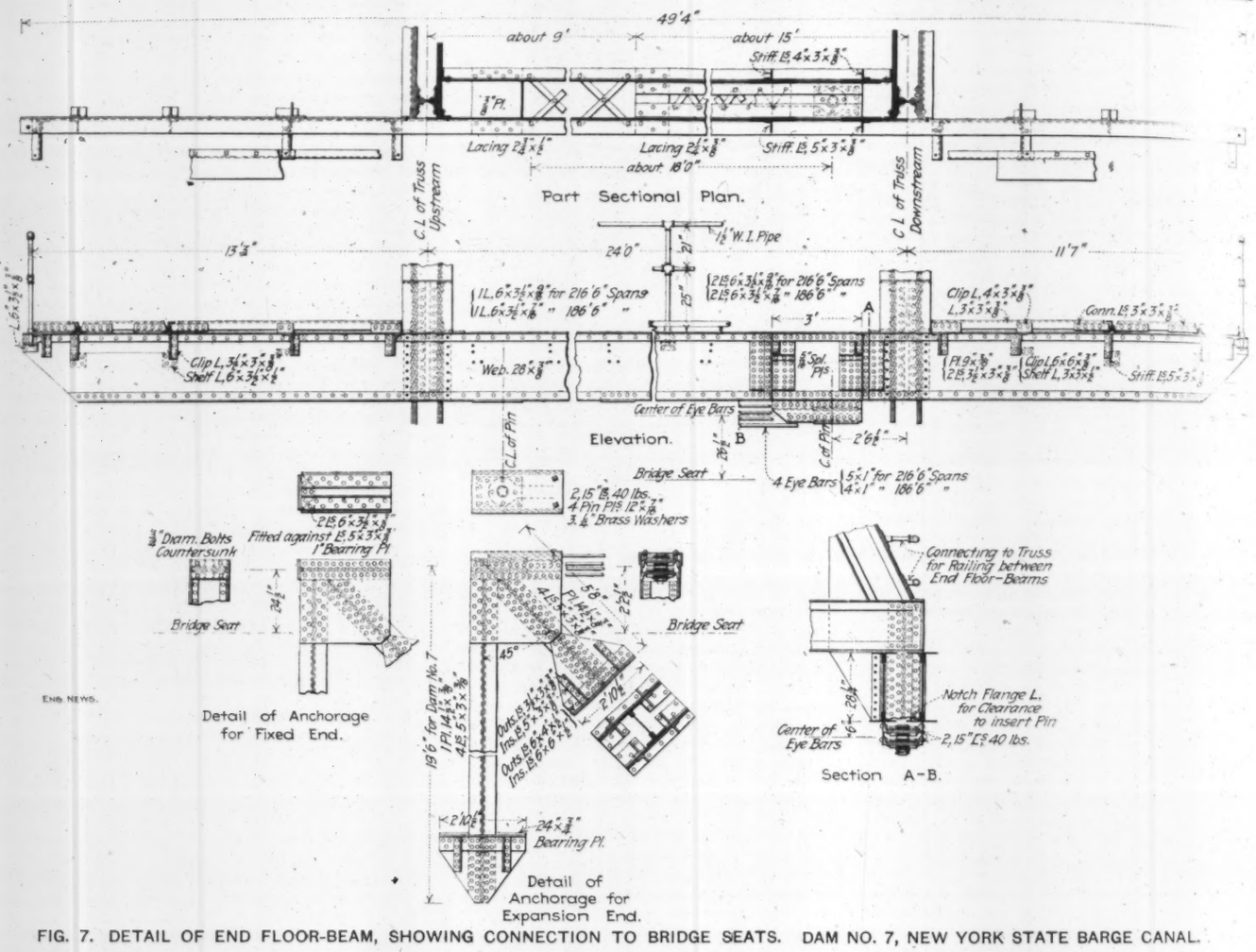


FIG. 7. DETAIL OF END FLOOR-BEAM, SHOWING CONNECTION TO BRIDGE SEATS. DAM NO. 7, NEW YORK STATE BARGE CANAL.

Fig. 12 are embedded. In the south bank of the river, the pier has a wing wall extending well up into the bank to shut off water and on the north side the pier is incorporated with the south wall of the lock.

Several of these bridge-dams are nearing completion (Figs. 1, 14) and it is expected to put two of them in operation next spring.

The design of the steelwork of these dams was made in the office of Mr. Wm. R. Davis, Chief Bridge Designer and Inspector, with the consulting advice of Mr. D. A. Watt, Supervising Engineer, who has made a special study of movable dams in this country and in Europe. Mr. Frank M. Williams is State Engineer and Surveyor and Mr. Wm. B. Landreth, Special Deputy State Engineer in charge of the Barge Canal work.

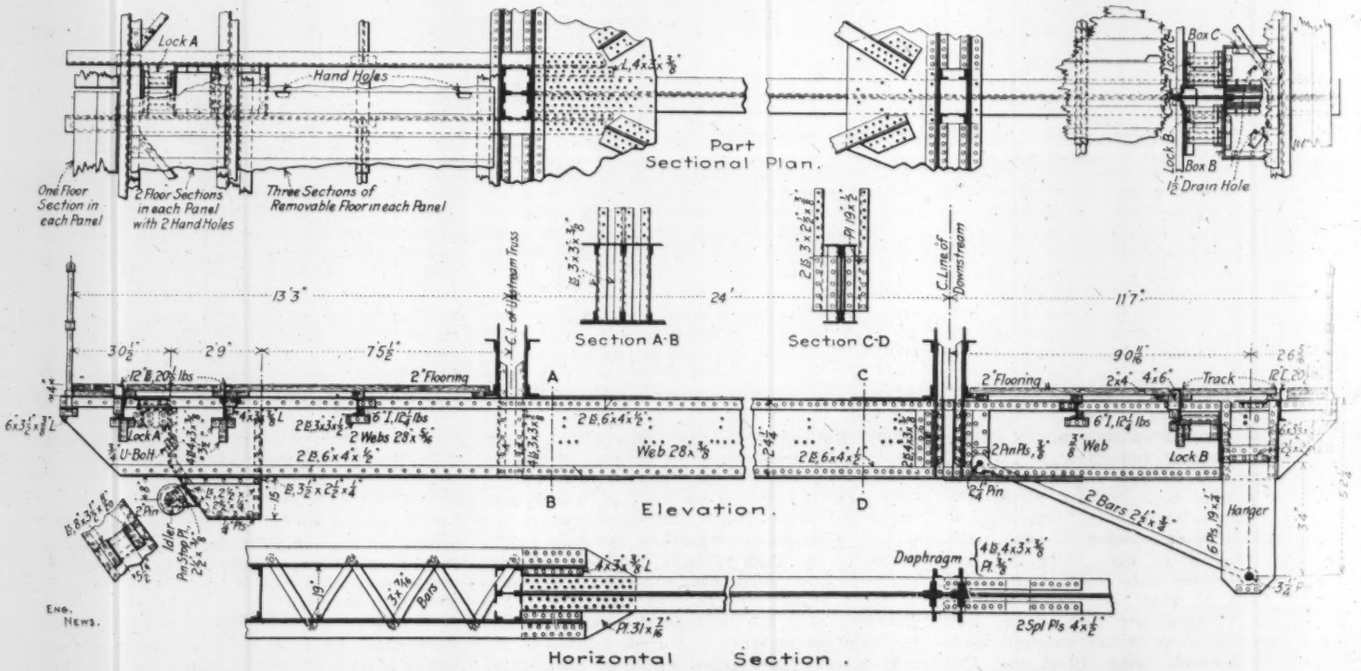


FIG. 8. DETAIL OF INTERMEDIATE FLOOR BEAM, SHOWING CONNECTION TO HANGER BEAMS, DAM NO. 7.

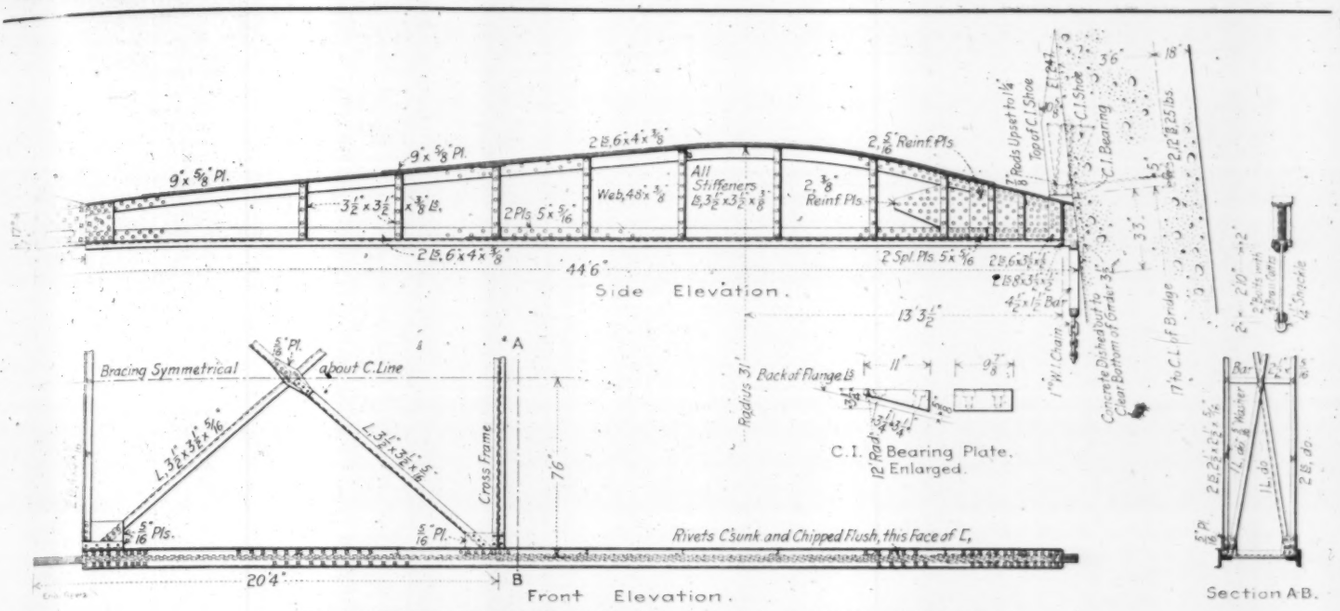


FIG. 9. DETAILS OF HANGER BEAMS, DAM NO. 7, N. Y. STATE BARGE CANAL.

Elements of a Constructive Franchise Policy.*

By DELOS F. WILCOX.†

For the sake of simplicity and directness I shall confine myself in this discussion to street-railway franchises. The principles suggested, however, will be applicable, with due allowance for modifying conditions, to franchises under which any local public utility is operated.

In making suggestions for a model street-railway franchise, we must stipulate at the beginning that existing perpetual, unlimited or indeterminate grants and grants expiring at different times should be terminated either by purchase, by condemnation, by forfeiture, or by negotiation. It is certainly impossible to inaugurate a correct franchise policy without being in a position to make this policy apply to existing lines.

We may start off, therefore, with the assumption that neither the city nor the state should show any mercy to forfeited or forfeitable franchises granted years ago in the days of dense darkness and corruption.

A constructive franchise policy must recognize the following objects to be attained:

(1) Adequate and continuous service.

(2) The protection of the capital invested in the business.

(3) The permanent upkeep of the property at the practicable maximum of efficiency.

(4) Extensions of service as needed.

(5) Reasonable and uniform rates.

(6) Unity in operation, subject to public supervision.

(7) The gradual authorization of the investment out of earnings.

(8) Continuous and effective control of the streets by the city, through the right at any time or at reasonable intervals to take over the lines and operate them or transfer them to other agents.

THE INDETERMINATE FRANCHISE.—I believe that the fundamental characteristic of a model franchise would be the terminable nature of the grant. I do not favor the indeterminate franchise in its Massachusetts form, under which the public authorities have a right to revoke the locations of a street-railway company without making any provisions for the purchase of the property. In practice, an indeterminate franchise of this nature is almost necessarily a perpetual franchise, except in the case of particular streets where new traffic conditions require the transfer of surface lines to other routes or to subways. The form of the indeterminate franchise which I favor would permit the city at any time after a certain initial period, or at frequent intervals after such period, to terminate the grant upon taking over the entire property of the company at a price to be determined by the cost of construction less the amount of the amortization fund already accumulated. This

*Part of a paper read before the National Municipal League, Buffalo, N. Y., Nov. 15, 1910. The portions omitted relate wholly to local street-railway matters in New York City.

†Chief of the Bureau of Franchises, Public Service Commission, First District, New York City.

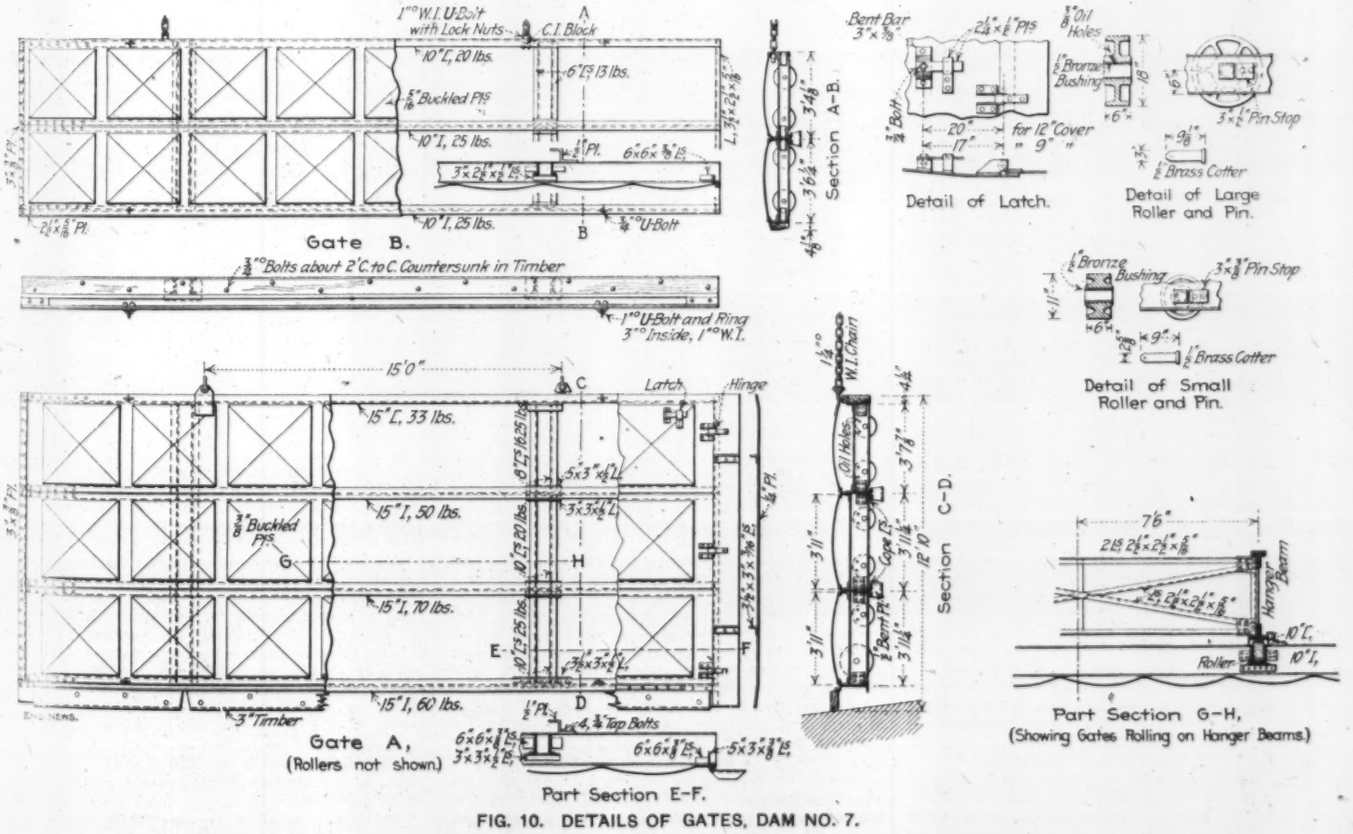


FIG. 10. DETAILS OF GATES, DAM NO. 7.

provision for purchase should not, however, apply to the revocation of locations on specific streets not integral and necessary portions of the company's route where such revocations are made necessary by changes in traffic conditions. In case of relocations, however, of any portion of the route, the net cost of the changes should be added to the capital account and become a part of the purchase price unless amortized before the city takes over the property.

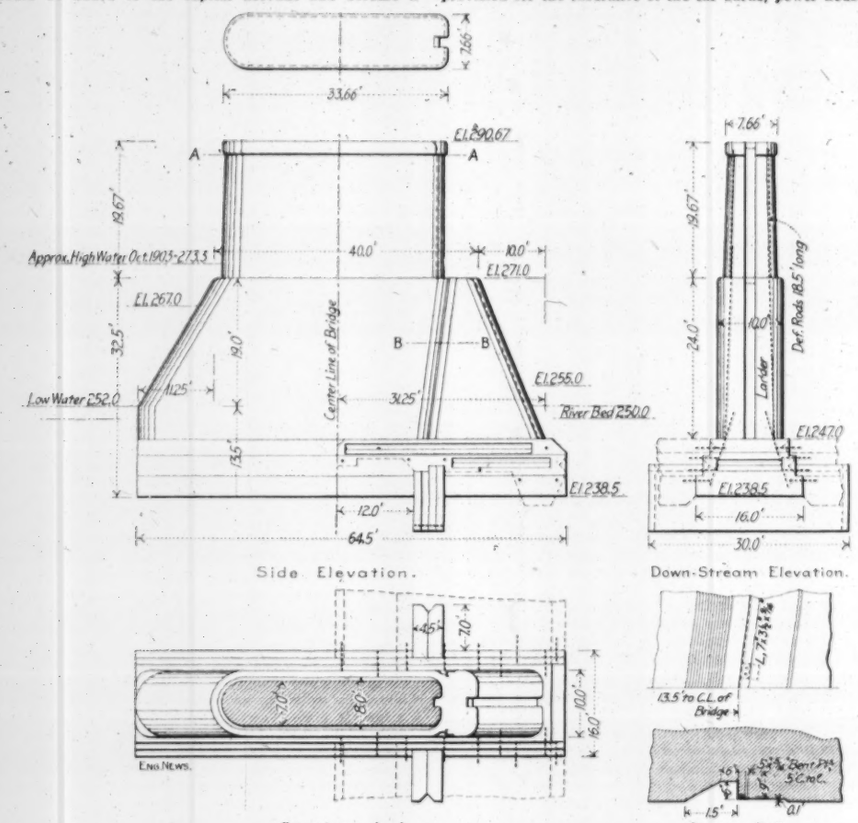


FIG. 11. PIERS FOR MOVABLE DAM ON THE MOHAWK RIVER.

The purpose of the indeterminate franchise as here outlined is threefold. In the first place, it provides for continuous public control of the city's street-railway policy. The desirability of municipal ownership and operation is a mooted question, but it can hardly be disputed that this generation ought not to attempt to foreclose the question against reconsideration and resettlement by generations to come. The indeterminate franchise leaves the city in full possession of its powers, so that its policy with reference to municipal ownership may be determined from time to time as future exigencies require. In the second place, the indeterminate franchise opens a way for the unification of street-railway systems where competition still lingers. Where there are several operating companies under the indeterminate franchise as here described, the city would be able to bring about the consolidation of all lines by taking them over for a new company to operate, or by causing the transfer to one of the existing companies of the lines of the other companies. The advantages of unity of operation both from the standpoint of the public and from the standpoint of those responsible for rendering street-railway service are too well recognized to require discussion here. In the third place, the indeterminate franchise even where operation is already unified and where the city does not desire to establish municipal ownership, would permit the city to transfer the entire system to new agents whenever the company already in control proves unable or unwilling to adjust itself to the conditions of intelligent and humble service. I may add that I think it would be fair to provide that in case the city terminates the franchise for the purpose of transferring the property to another private company, a bonus of 10% or 15% should be paid in addition to the price for which the city can take over the property for municipal operation. This principle has been recognized in the Chicago Settlement Franchise.

DISPOSITION OF EARNINGS.—In my judgment the intimate control of the street-railway service demanded by modern conditions can be made most effective by the inclusion in the franchise contract of certain definite requirements in regard to the disposition of revenues. Particularly if the purpose of such intimate control is to compel adequate service at reasonable rates, the maintenance of the property at the highest practicable standard of operating efficiency, and the gradual writing off of the capital invested, it appears absolutely necessary to stipulate the general rules which shall govern the company in the use of its gross earnings.

I would therefore stipulate that out of street-railway revenues there shall first be paid whatever may be necessary to meet operating expenses in the broadest sense of that term. I would include in operating expenses such taxes as may be levied against the company or its property under the laws of the state. I would include specific provision for the insurance of the car barns, power-houses and rolling stock against destruction by fire. I would include specific provision for the maintenance of an accident fund, out of which shall be paid the claims of tort creditors as well as the necessary legal expenses of the company in settling or defending damage suits. To meet this particular class of expenses requires from 3 to 11% of the gross earnings of the various surface street-railway systems of New York City. Under present conditions, of street railways, this fund from year to year, and such portions of the fund as cannot profitably be expended on current maintenance and renewals, should be permitted to accumulate for future use. This fund should be sufficient to provide for depreciation of every kind, including obsolescence, inadequacy, age and deferred maintenance, excepting only the depreciation allowed from the 100% standard of a new plant to the 75% standard of an old plant maintained at its maximum efficiency. This last item of depreciation is sometimes called normal wear. It represents the necessary shrinkage of the property provided at the start by the original investment. This shrinkage is something that cannot and need not ever be restored. It should be taken care of not by a depreciation fund, but by the early amortization of a portion of the capital. While it seems desirable to insert in the franchise contract specific percentages of gross revenues to be set aside for the various funds, provision should be made for the readjustment of these percentages from time to time if such readjustment seems necessary in the light of experience.

After providing for the payment of operating expenses of every kind and nature as hereinbefore described, the franchise should authorize the company as the next draft upon revenues, to withdraw a sum sufficient to pay a reasonable minimum return or, say 5 or 6% upon the amount of the capital actually invested. The amount of the investment, so far as the franchise is concerned, should not be determined by the aggregate par value of the stocks and bonds of the company outstanding at any particular time. The regulation of nominal capitalization may well be left to the state authorities. [illegible] franchise should make definite provision, how[illegible] determining from time to time the capital value [illegible] ried on the company's books as the basis for [illegible] guaranteed returns upon investment, and as [illegible] the purchase price of the property if the [illegible] at any time determine to take it over. S[illegible] say at this point that the capital upon whi[illegible] pany is allowed a fixed annual return shou[illegible] the cost of construction, including the elem[illegible] liminary and organization expenses and all [illegible] ments legitimately entering into such cost i[illegible] comprehensive sense.

AMORTIZATION.—After the earnings of the [illegible] have paid a fixed minimum upon capital invested, th[illegible] to be provided for is the amortization of the [illegible] self. In the first place, immediate provision [illegible] made, if possible, for the amortization of 25[illegible] capital, representing that portion of the prope[illegible] will be worn out in approximately ten years [illegible] commencement of operation, never to be restore[illegible] retically, this portion of the capital should be [illegible] within the first ten years of operation, but inasmuch as in the case of an entirely new road the earnings of the property during the first few years may be comparatively scant, it will not be possible in all cases to follow this rigid rule. Regular payments to the amortization funds should be made in the shape of a certain percentage upon the capital invested rather than as a percentage of gross receipts. It would require the payment of approximately 2% a year, with the fund accumulating at the rate of 4% per annum, to provide for the retirement of 25% of the capital at the end of ten years.

While it may not be possible in some cases to set aside this full amount in the early years of operation, there is no reason why this charge should not be made before the investors are permitted to earn anything more than the fixed minimum rate of profits. After the accumulations in the amortization fund have become equal to 25% of the original investment, provision should be made for the permanent writing-off of that portion of the company's capital account, and thereafter the allowance for interest on investment should be based upon the capital as so reduced.

What further provision shall be made for amortization after the capital has been brought down to correspond with the permanent status of the property, will depend upon the controlling theory as to the permanent capitalization of utility plants. To my mind, it is of as much importance that a street-railway system under private operation should be paid for as that a water-works plant under municipal operation should be paid for. It seems to me to be a desideratum in the case of all public utilities, whether municipally or privately owned, that provision should be made for the amortization of the entire capital out of earnings within a period of from 25 to 30 years. The increasing burden of municipal debt, even though city bonds are retired when due, practically prohibits the acquisition by the city of public utilities whose capital account has been steadily increasing from the day they were first constructed. The legitimate burdens of the future in a growing city are always greater than the burdens of the present. Every new utility should pay for itself within a generation or two, so as to prevent the heaping up of burdens on the shoulders of the citizens of the future. When an energetic young man goes into debt to buy a farm, he is not satisfied to pay interest indefinitely on the amount of his mortgage. He considers it a matter of plain business sense and patriotic duty to pay off the mortgage so that he and his children after him will actually own the farm. In like manner, the city that is guided by common sense and regard for its future will see to it that the public streets and all the fixtures in them are paid for as soon as possible and relieved of the enormous burden of debt that is originally laid upon them, by the issuance of municipal bonds and public-utility securities.

The amortization fund provided for in street-railway franchises should be put into the hands of trustees, with authority to invest in the stocks and bonds of the company wherever that is possible, and otherwise in ap-

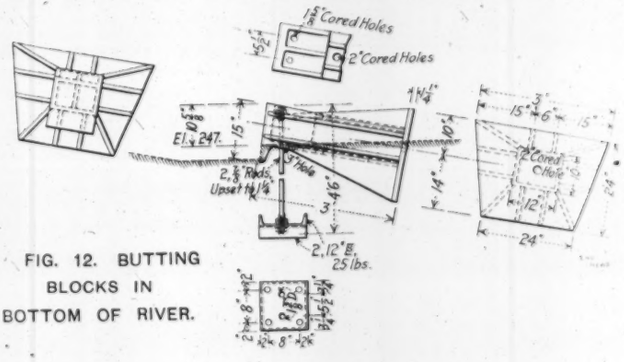


FIG. 12. BUTTING BLOCKS IN BOTTOM OF RIVER.

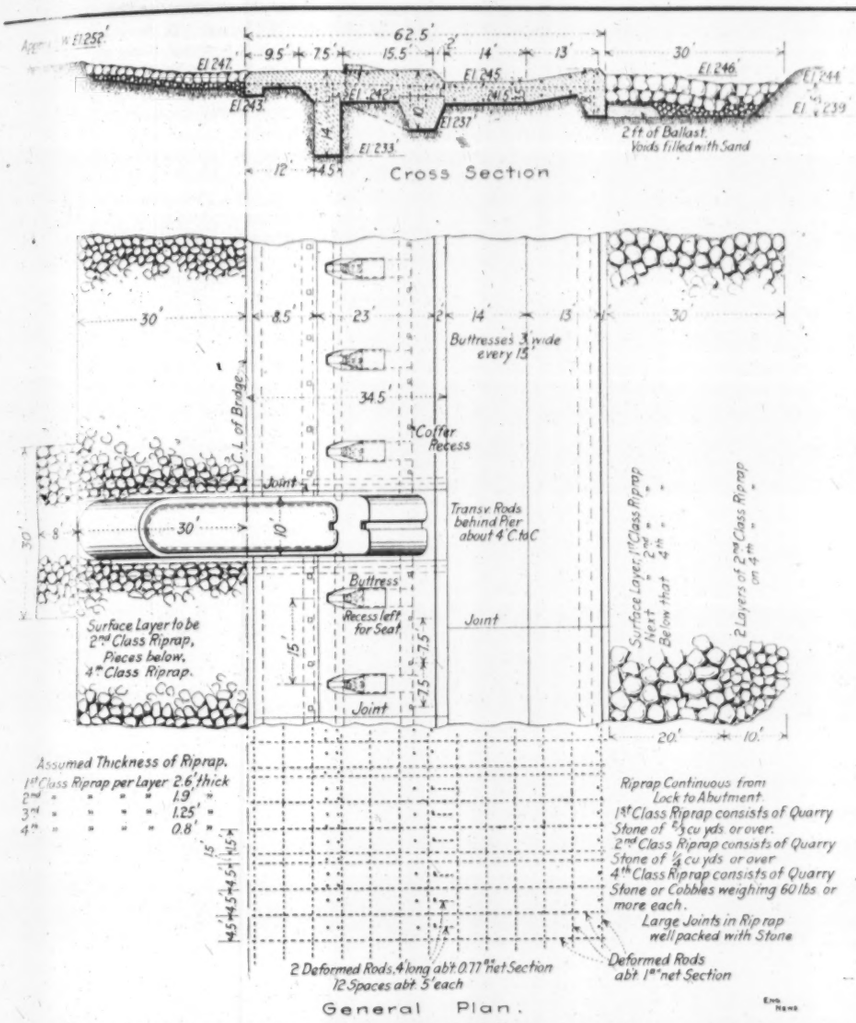

Cross Section
General Plan.
Surface Layer to be 2nd Class Riprap, Pieces below, 4th Class Riprap.
Buttresses 3' wide every 15'
Coffer Recess
Transv. Rods behind Pier about 4' C. to C.
Recess left for Seat
Joint
Assumed Thickness of Riprap.
1st Class Riprap per Layer 2.6' thick
2nd " " " 1.9' "
3rd " " " 1.25' "
4th " " " 0.8' "
Riprap Continuous from Lock to Abutment
1st Class Riprap consists of Quarry Stone of 2/3 cu. yds. or over.
2nd Class Riprap consists of Quarry Stone of 1/4 cu. yds. or over
4th Class Riprap consists of Quarry Stone or Cobbles weighing 60 lbs. or more each.
Large Joints in Riprap well packed with Stone
2 Deformed Rods 4' long abt. 0.77" net Section 12 Spaces abt. 5' each
Deformed Rods abt. 1" net Section
2 Layers of 2nd Class Riprap on 4th
Surface Layer 1st Class Riprap Next 2nd " " Below that 4th " "
2 ft of Ballast Voids filled with Sand

FIG. 13. CROSS-SECTION OF RIVER UNDER MOVABLE DAM NO. 7, MOHAWK RIVER, SHOWING PAVING AND BUTTING BLOCKS.

proved outside securities bearing interest or paying dividends at not less than a specified percentage.

After providing for operating expenses, interest on investment and amortization charges, the franchise should provide for the accumulation of a contingent reserve fund for the purpose of taking care of any deficits which may occur in lean years in respect to any of the obligations already provided for. Into this reserve fund should be paid perhaps 1% of gross revenues, until the accumulations of the fund reach a maximum of, say, 5% on the amount of capital invested in the property.

Any balance of gross receipts remaining in the treasury of the company at the end of any fiscal year, after operating expenses, return on capital and amortization and contingent reserve charges have been paid, should be treated as net profits, and should be divided in some equitable proportion between the company, the city and the employees of the road. I would provide, however, that the city's share in the net profits, whatever that share may be, should be turned into the amortization fund, in addition to the regular payments to that fund, so as to hasten the time when the capital can be written off and the street railways can be operated either as a municipal or as a private enterprise without the burden of fixed charges. Careful students of public utility problems are pretty well agreed that franchise utilities should not be operated for the purpose of bringing into the city treasury a revenue for the relief of the general taxpayers.

DIVISION OF NET PROFITS.—As a tentative basis for the division of net profits, I would suggest that 50% be assigned to the city to be used as I have already intimated; 25% be turned over to the company as an additional return upon investment, and 25% be turned into an employees' benefit fund. I would provide for the distribution of this fund by trustees according to plans devised from time to time to encourage and reward efficiency, economy and care in the operation of the road. At the present time, without taking into account the grave dangers and the enormous losses attendant upon street-railway strikes, we find all too many cases where the employees, falling victims to petty temptation or attempting to imitate on a small scale the peculations of the man higher up in the street-railway business, "knock down" fares or neglect to collect them to such an extent as to cause a serious direct loss to the company and an indirect loss to the public, which must depend upon the earning power of the road for the maintenance of adequate service. It is certainly of the utmost importance to the city in the granting of a street-railway franchise to a private company, that all possible provision shall be made to insure the loyalty and efficiency of the employees. The distribution to the employees of a share of the net profits of the business according to some wise plan, based on the recognition of special merit, would, I am sure, redound to the common benefit of the public and the investor.

EXTENSIONS. — No street-railway franchise contract is adequate unless it reserves to the city the right to require from time to time the construction of extensions as needed. The proper development of the local transit system is so important a factor in the social, economic and political welfare of a city, that the right to initiate and control the development in accordance with the demands of public policy should never be surrendered by the municipal authorities. The arbitrary right to compel extensions wherever desired might be abused by an ignorant or reckless city government. It is probably necessary, therefore, that provision should be made for an appeal as to the necessity and reasonableness of a proposed extension from the order of the local authorities to a state commission or to the courts.

The procedure in cases where extensions are ordered should be very carefully worked out, so as to prevent impossible requirements on the one hand, and unreasonable delay and litigation on the other. In order to relieve the situation where extensions are needed which a company could not in justice be required to build at its own expense, the city should reserve the right to require the company to operate extensions constructed by the city on the assessment plan, or by the property owners specially interested in securing the extension.

RATES OF FARE.—In a street-railway franchise drafted in accordance with the principles here proposed, I would provide for flexible rather than arbitrary rates. It is highly desirable that every urban community constituting a single unit of street-railway operation, should have uniform rates of fare, with universal transfers, subject to reasonable regulation. The particular rates to be charged, however, should be determined by the necessities of the case. There is no reason to believe that unless possibly in the very largest urban territories, a higher rate than five cents for adults, with half fare for children between the ages of six and twelve years, would be required. We should not flinch, however, from the fixing of a rate that will meet the requirements of a constructive street-railway policy as here outlined. It might be desirable to incorporate in the franchise a sliding scheme of rates to be readjusted automatically, in a manner similar to that set forth in the settlement ordinance that is now being tried out in Cleveland.

ARBITRATION.—Continuity of operation is so fundamental a requisite in street-railway service, that every necessary means should be taken to insure it. On this account the relations between the company and its employees whenever they are such as to threaten interruption or disintegration of service, become a matter of paramount interest to the city. I would therefore stipulate in the granting of any street-railway franchise that the company shall bind itself to submit any questions of dispute arising between it and its employees to arbitration when requested to do so by the city.

CAPITAL ACCOUNT AND PURCHASE PRICE.—There are two methods of determining the price at which a public utility may be taken over by the city or its licensee. According to one method, the property is appraised at the time of purchase. According to the other method, the value of the property is agreed upon in the franchise itself or at the time of construction. The uncertainties attendant upon appraisal at some indefinite time in the future are so great that I believe the city's interests will in general be better conserved if the purchase price is based upon the cost of construction less the amount of capital amortized, than by any other plan.

I am convinced that in order to get a scientific street-railway franchise policy actually established, a city may well afford if necessary to accept a valuation of an existing plant, properly maintained, that would include this element of capital representing property that has disappeared. Under such circumstances the same amortization provision would have to be made as for new.

In closing this paper, I desire to quote a brief passage from an address by Mr. Charles V. Weston, President of the South Side Elevated Railway Co., of Chicago, before the American Street and Interurban Railway Association at Atlantic City, N. J., Oct. 13, 1910. I have been particularly impressed with the remarks I am about to quote, for the reason that they seem to indicate a recognition on the part of a practical railroad man of the necessity for the application of at least one of the fundamental principles outlined. Mr. Weston says:

> Referring specifically to the matter of speculation, if the street railways are to be recognized and tolerated as legitimate business enterprises, in which the owners and the people have a mutual and equally important interest, these enterprises must be permanently removed from the field of stock manipulation, which has for its sole purpose the drawing out of the people's money in payment for that which does not represent intrinsic value.

FIG. 14. NEAR VIEW OF THE CRANESVILLE DAM NO. 6, SHOWING DETAILS OF HANGERS.

A Rock-Transporting Cableway for the Harbor Works of Rangoon, Burmah.

In the extensive improvements which are now being made to the Harbor of Rangoon, in Burmah, one of the most important features is a large rubble training wall which is being built to retain the channel of the river immediately opposite the city. This part of the country is all alluvial ground with hardly any available stone, so that it became necessary to look elsewhere for the rock with which to build the wall. The nearest

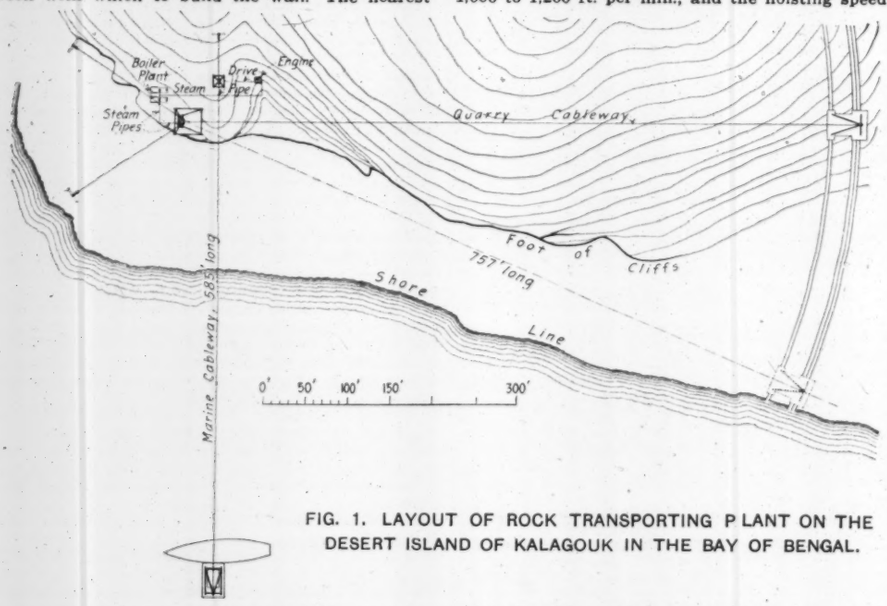


FIG. 1. LAYOUT OF ROCK TRANSPORTING PLANT ON THE DESERT ISLAND OF KALAGOUK IN THE BAY OF BENGAL.

supply of sufficient size—about 1,000,000 cu. yds. will be necessary before the work is completed—was found to be on the Island of Kalagouk, some 130 miles from the city. Kalagouk is a deserted island consisting mainly of a granite mountain rising almost precipitously from the sea. Upon it has been built a rock excavating and transporting plant, and there are now living there about 1,000 natives operating the works.

The problem was to excavate into a solid hill of granite and to load this stone on barges which, on account of the shoals, could not anchor nearer than 600 ft. to shore. For the work, the contractors, Messrs. Fraser & Chalmers, Ltd., of London, England, called in the Lidgerwood Mfg. Co., of New York, and this firm designed and built the plant described herein. No little part of the interest in the plant lies in the fact that the rock removal is all being done under most primitive methods, as the type of labor shown in Fig. 2 will show, although the machinery which transports the rock once removed is of the most modern type.

Fig. 1 shows the layout of the island and the plant. Although we have no direct information on the subject, it appears that the contours there shown are drawn to a 10-ft. interval, so it will be seen that the hill is very steep. Excavation is being made on the shore of the island shown at the lower end of the map across the entire distance there drawn, and is proceeding toward the interior as the rock is removed. The transporting plant consists of a so-called "quarry cableway," paralleling the rock face, and a "marine cableway," crossing the former at right angles and reaching to a fixed tower alongside of which the transporting barges anchor. The quarry cableway consists of a fixed pivotal head tower 85 ft. high and a traveling tail tower 74 ft. high, moving on radial tracks through what is expected to reach at least a 48° arc. The cable is 840 ft. long, and the distance between towers is 757 ft. 7 ins. The marine cableway has a 30-ft. head tower and a cable extending 585 ft. out into the sea to a 64-ft. tail tower built on piling driven into the soft bottom. These marine towers were built on the "duplex" plan so that if necessary a second parallel cableway might be added if required. Both cables are controlled from a steam boiler plant, shown on the drawing, from their head towers on shore near the plant.

In operation the broken rock is loaded by hand labor on the open skip traveling on the quarry cableway. The skip is then pulled in towards the head tower and dropped immediately under the marine cableway, where it is picked up by the carriage and swung out on the marine cableway to the barge. These skips measure 8 × 8 × 2 ft. and carry approximately 5½ tons, with each load. The carriage speed upon the cables is 1,000 to 1,200 ft. per min., and the hoisting speed is 200 ft. per min. The main cables are of locked wire rope 2¼ ins. in diameter.

For the transportation of the rock, specially designed 1,000-ton steam hopper barges have been built. These barges are loaded at the tail tower of the marine cableway during the day and proceed to Rangoon by night. The distance from the island to Rangoon is about 135 miles, so it is evident that more than one barge must be provided to ensure continuous operation, although we are not informed as to just how many there are. This plant has now been in operation for about a year and is proving exceptionally successful.

Fig. 3 shows the head tower of the quarry cableway with the boiler house in the background. Crossing at right angles to the cableway from this head tower may be seen the marine cableway with its traveling carriage in air. Fig. 4 shows the tower at the ocean end of the marine cableway. It was necessary to have at least 20 ft. of water here, and as there is a 20-ft. tide the base of the tower had to be at least 40 ft. above bottom. The additional 13 ft. to the tower deck, in order to clear the deck of the barge, makes a very high structure, which had to be thoroughly interbraced. It will be noted that the head piece is provided in duplicate, in case additional service is required.

The improvements at the port of Rangoon which require this plant are of considerable interest. They were described in "The Engineer" of London, in the issue of July 16, 1909. From that article we abstract the following description:

Rangoon is a city of about 250,000 inhabitants, the main seaport of the great Irrawaddy valley. The Irrawaddy River extends from the Gulf of Martaban, at the eastern end of the Indian Ocean, north to Mandalay and above in Upper Burmah, and is navigable for more than 500 miles. It reaches the gulf through a large number of mouths running through a triangular alluvial delta about 150 miles long on each of its three sides. The Rangoon River is one of its principal outlets and traverses the eastern side of the delta, and the city of Rangoon lies at the head of a broad stretch at the end of the river about 40 miles from the gulf. The import trade of Rangoon began to take on importance about the time of the formation of the Port Trust in 1880, and by 1900 it had reached a figure of over $90,000,000 a year. In that year, Mr. George C. Buchanan, M. Inst. C. E., was made Chairman and Chief Engineer, and under his direction the work was begun in 1901 of building wharves and other accommodations for both inland and seaboard trade. This included reclaiming 15,000 sq. yds. of foreshore and building a retaining wall 2,720 ft. long, new import wharves 1,300 and 1,800 ft. long, respectively, brick and iron warehouse sheds with a floor area of 308,000 sq. ft., a port road, pontoon landing stages and other improvements costing altogether $3,500,000.

As a result of all this work, it was intended and expected to have 28 ft. of water alongside of the main wharves at low water, and by dredging a shoal in the harbor vessels of the deepest draft were expected to be able to come to the wharves full laden instead of lightening a portion of their cargo. The value of all this work was suddenly threatened, in the first part of this century, by the action of the river, which began rapidly eroding the bank opposite the city at a bend just above the harbor. It ate into the bank until the river was 6,000 ft. wide at that point, although it is only 2,500 ft. wide at the harbor, and it shifted the deep water channel to the opposite bank, silting up the old channel along that part of the city's front and threatening to destroy the entire harbor. To overcome this difficulty, Mr. Buchanan, in 1903, proposed the building of a training wall 2½ miles long, to hold the

FIG. 2. NATIVE BURMESE LABORERS WORKING IN CONNECTION WITH THE CABLEWAY SYSTEM ON KALAGOUK ISLAND.

river in its old course, and to dredge a new channel along the city front through the flat that had been formed. The wall would have to be built in water from 10 to 70 ft. deep at low water in a tidal current of four knots both on the ebb and the flood. This scheme was submitted to Messrs. J. W. and C. P. Meik, and to Dr. E. L. Corthell,

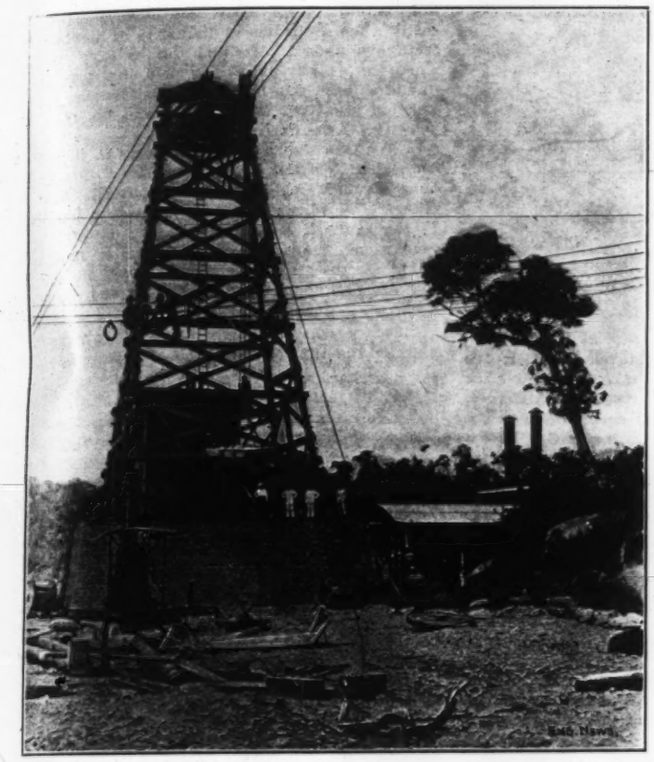


FIG. 3. HEAD TOWER OF THE QUARRY CABLEWAY.

(Showing the skip on the quarry line and the dumping carriage on the marine line at right angles to it.)

and after being approved by them, was adopted and started.

The work of building the training wall was started by first placing as a foundation fascine mattresses along the whole end of the shore to be covered, using to sink them granite rock to the depth of 5 ft. Upon this the wall is to be built by dumping granite from the self-dumping barges, noted above, to low water mark. Above this a block stone wall 5 ft. high is to be built, and above that a pitch slope to high water mark.

The drawings and half-tones, with the description of the works were furnished us by the Lidgerwood Mfg. Co.

Engineering Testimony in Court Actions.

By G. B. ZAHNISER.*

The use of plans and profiles in the trial of civil and criminal cases has increased to such an extent that a word or two of comment on this work may be in season. Many instances have come to the writer's notice, where good honest field work, done by the engineer has been subjected to unmerited ridicule and has had doubt cast on it in court by want of a little care in the presentation of the data.

A plan to be used in evidence (call it a "court map" for want of a better term) is simply the arrangement on paper of certain conventional symbols to show to another things seen and done by the engineer. Few lawyers and fewer jurymen can read the plan in evidence easily and quickly, so it behooves the engineer in making such maps to avoid certain technicalities and to be direct and clear. To this end the title of the map should set out the township or ward, the county and state in which the work is located, also the scale, meridian, date and the engineer's name, and usually, in a note, the names of those present at the survey. It is surprising how many "court maps" are offered in evidence on which one or more of these evidently necessary things is omitted.

In addition, the title should set out what the map is intended to show. It is here that so many legal maps are weak. For instance, a beautiful plan showing splendid field and office work in a land-line case was practically laughed out of court, because the first line of the title in very ornamental type read "*Ponere positu litem*" (literally, "To put the law suit in position"). The engineer translated this bit of affectation as, "To settle the law suit," under the firm belief that his work had done so. This case was lost by the engineer's client because, among other things, of the bad impression the engineer made as a witness, the laugh at his affected title going far to create the impression.

Again a title reads "Plan Showing Place Where John Doe was Murdered," or "Plan Showing Place Where John Doe Struck Billy Patterson," and the like. All such titles are wrong. It is not for the engineer to set out that John Doe was murdered, or that Billy Patterson was struck. This is the very business of the court, and the engineer must remember that he is only one witness of the many whose testimony is considered. His plan is simply to record and make clear his own evidence.

Again, nearly every symbol or mark on a "court map" should be named, such as rail fence, wire fence, brick house, barn, chair, table, road, door, low-water line, top of slope, etc., etc. Name all the lines and symbols on the plan so that there can be no possible mistake as to what is meant by them, even by the average juryman. Do not put anything on the plan that you cannot name, i. e., meaningless lines. On a certain court drawing, a section of a reverbatory furnace was shown with a lot of wavy lines to show the alleged path of the flame. The engineer who made the plan (very satisfactory in every other way) was soon driven to admit that these wavy lines were imaginary things and the jury got the idea that the section shown was also mostly imaginary. In this case one or more arrows marked "Direction of Flame" or "Path of Gases" would have been proper, and if asked the engineer could have stated why they were thus placed.

The closer he confines his testimony to what he has seen and measured (in the broad sense) the better witness he is. When asked his opinion as an expert, that is another matter, but let him where possible keep his opinions off his map. This remark applies mostly to land cases where an engineer who values his reputation will do well to set out by his plan and evidence just what he did and how, and little more. When by his plan and evidence he undertakes to "establish" or "settle" or "decide" the very matters in question before the court, it is an intolerable bit of ignorance and conceit that soon meets its just dues.

Contours mean little to the layman and should be avoided in legal work when possible. Use sections. Profiles and sections must as a rule have one scale for horizontal and another for vertical, but when possible, make both scales the same in legal work, they are less open to the insinuations of cross examinations. When necessary to use and explain contours, the familiar illustration of a pond of water and its shore lines for different depths of water is as good as any explanation for the witness stand. A plain illustration such as this catches the attention and makes clear something technical.

Mr. J. F. Wallace, when Chief Engineer of the Panama Canal, and before a Senatorial investigating committee, was asked as to the safety of the Gatun dam with the immense acreage of water back of it. He answered, "The dikes of Holland keep out the Atlantic Ocean." This illustration is an engineering classic in quickness and clearness. Imagine him saying even to senators, "The reason it is safe is, that the pressure varies directly as the depth, and is independent of the volume." If engineering expert witnesses will avoid such answers on the witness stand, they will escape much of the present odium that goes with the name "expert."

Strong partisanship on the witness stand by an engineer is always bad—for himself and for his client. If the whole truth as seen by an engineer is not wanted by his client, the engineer had better not testify. At best, the collection of conventional symbols, his map, is sure to be colored by his judgment of the facts, but it is his duty to so honestly make clear the golden side of the shield which he sees, that those who hear his testimony will be convinced that the silver they see on the other side of the shield is just a wash anyhow.

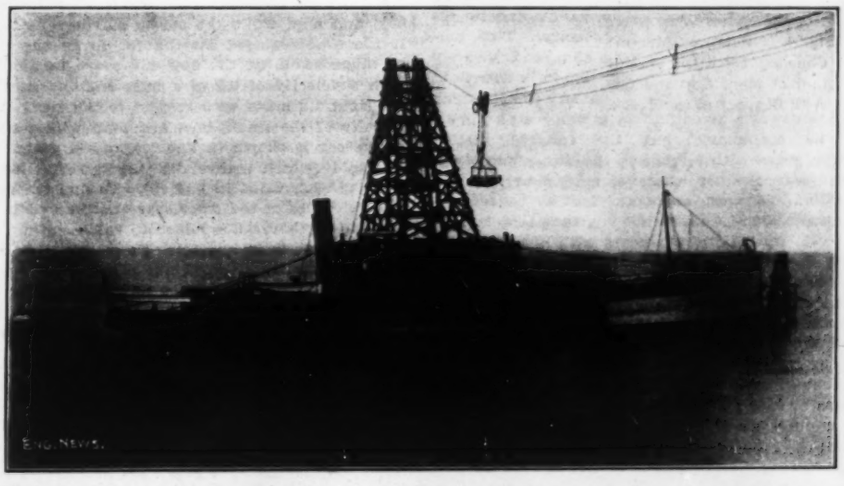


FIG. 4. BARGE LOADING ROCK AT THE TAIL TOWER OF THE MARINE CABLEWAY.

*Civil and Mining Engineer, Clendenin Block, New Castle, Pa.

Analysis of Velocity Ratios of Epicyclic Gear Trains.

By A. LEWIS JENKINS.*

Epicyclic trains of gears offer many fascinating problems to those interested in machines involving differential or equalizing mechanisms or rotating parts having high ratios of velocity, as well as to those who find it a pleasure to sacrifice their surplus mental energy to the goddess of puzzledom. To those who adjust and operate certain automatic and other machine tools, a definite knowledge of some method for determining the velocity ratio of epicyclic trains is a valuable asset.

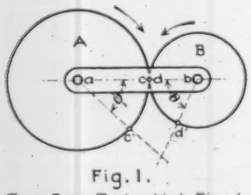


Fig. 1.
Two Gear Train; Link Fixed.

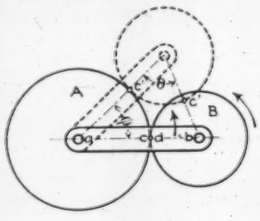


Fig. 2.
Two Gear Train; One Gear Fixed.

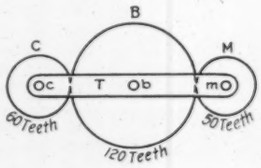


Fig. 3.
Three Gear Train.

SIMPLE EPICYCLIC TRAINS.

The wide application of the epicyclic train to various classes of machinery has led to its being variously known as planetary, differential, oscillating and wabble gearing, under which names it has become a familiar mechanism.

An epicyclic train consists of two or more gears so connected as to allow one or more of them to revolve around a fixed center and rotate on its axis. The word "epicyclic" is derived from the Greek words *epi* meaning "upon," and *cyclos* a "circle," and intended to convey the idea of one circle rolling around the outside of another. This implies a condition which exists in the case of external gearing, but numerous trains involving a pinion rolling inside of an annular gear could have been called "hypocyclic" (*hypo* meaning "under") with the same degree of definition.

Velocity Ratios of Simple Epicyclic Trains.

The simplest form of gear train consists of two or more gears connected by a rigid link or frame as shown in Figs. 1 and 3. If the link is stationary and one of the gears is rotated through one revolution all the other gears will move a definite amount, depending upon the number of teeth in each gear; or if one of the gears is running at a given velocity all the other gears have a definite velocity. This motion and velocity is in respect to the link, which was assumed to be stationary, but the relative motion of the gears with respect to the link remains the same regardless of whatever motion be given to the link. A most important fact to be remembered in connection with epicyclic gears is that the velocity ratio of the gears with respect to the link can not vary. They are formed by a combination of equivalent linkages and pins in such a way as to produce a definite motion when one of the links is moved with respect to any other and this is called a kinematic chain. A mechanism may be defined as a kinematic chain with one link fixed; hence by fixing any one of the gears or the link in Fig. 3 it is possible to get four different mechanisms.

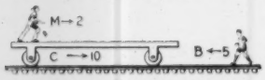


Fig. 4. Relative Motion: Showing Direction of Motion of Man, Boy and Car With Respect to the Track.

Suppose the gear A in Fig. 1 is rotated clockwise through an angle ϕ or arc cc'. This will cause the gear B to rotate through an arc $dd' = cc'$ and an angle θ. The relation between these angles is such that $\phi \times ac = \theta \times bd$, or $\frac{\phi}{\theta} = \frac{bd}{ac}$.

Since the wheels turned through these angles in the same period of time, $\frac{\phi}{\theta}$ is the angular velocity ratio. From the above equation it is seen that this ratio varies inversely as the ratio of the radii.

In Fig. I the gears rotate in opposite directions with respect to the link. The relative motion of these gears is analogous to the relative motion of two men starting from a post and walking in opposite directions at different velocities. If one man walks at the rate of 3 mi. per hr. and the other at 5 mi. per hr. with respect to the post, this velocity with respect to each other, is the rate at which they are separating is $3 + 5 = 8$ mi. per hr., or the sum of their velocities with respect to the post. If the gear A rotates clockwise through an angle ϕ and B rotates counter-clockwise through an angle θ, with respect to the link, their angular motion with respect to each other is $\phi + \theta$.

Fig. 2 shows the configuration of this train when the gear A is fixed and the link turned about the center a through an angle ϕ. In this case the relative motion of the link with respect to the gears is the same as in the case shown in Fig. 2, but the velocity of the gear B is now taken with respect to the gear A instead of the link. Hence the gear B turns through an angle equal to $\phi + \theta$.

ANALYSIS OF RELATIVE MOTION BY TABULATION.—A clear conception of relative motion may be gained from the analysis of Fig. 4 which shows a flat car moving at the rate of 10 mi. per hr., a man walking on the car in the same direction at 2 mi. per hr., and a boy walking on the track in the opposite direction at the rate of 5 mi. per hr. The relative velocity of each body with respect to the other is tabulated in Table I, the positive sign denoting motion to the right and the negative sign denoting motion to the left. The first line (a) in the table shows the velocity of the car, boy and man in miles per hour with respect to the track, the second line (b) shows the distance traveled by the car, boy, and man while the car is moving one mile. If the time required for the car to go one mile be taken as unity, the boy will move to the left with a velocity of 0.5 of a mile and the man to the right 1.2 miles with respect to the track. The velocity of the track, boy, and man with respect to the car is shown in line (c) and is gotten by adding 1 (which makes the velocity of C in (c) zero) to each value in line (b). To find the relative velocities of the track, car and man with respect to the boy, 0.5 is added to values in line (b) or 1.5 to values in line (c). From this it is seen that the velocity of any three of the bodies with respect to the fourth may be found by stating the relative velocities as shown in line (b) and adding or subtracting such a value as will make the velocity of the fourth body equal to zero.

TABLE I.—RELATIVE MOTIONS OF MAN, CAR, BOY AND TRACK SHOWN IN FIG 3.

	T	C	B	M
(a).....	0	+10	−5	+12
(b).....	0	+ 1	− 5/10	+ 12/10
(c).....	−1	0	−1 5/10	+ 2/10
(d).....	+ 5/10	+ 1 5/10	0	+ 1 7/10
(e).....	−1 9/10	− 5/10	−1 7/10	0

(a) Velocities of car, man and boy with respect to the track.
(b) Miles traveled in 1/10-hour or distance traveled by man and boy with respect to the track while car travels one mile.
(c) Miles traveled by man and boy with respect to the car while the car is moving one mile.
(d) Miles traveled by track, car and man with respect to boy while car is moving one mile.
(e) Miles traveled by track, car and boy with respect to man while car is moving one mile.

This method of analysis which may be applied to problems involving any number of men, boys and cars, provided their motions in each case are in the same vertical plane, is also applicable to any epicyclic gear train. In the latter case, of course, angular velocity takes the place of linear velocity. The velocity ratios of the several gears are first written down for the case where the link is stationary. This can always be done easily when the ratios of diameters or numbers of teeth are known. To find the velocity ratios when any gear is fixed, it is then only necessary to add to each relative velocity the number (positive or negative) which will make the relative velocity for the fixed gear zero.

In Fig. 3 is shown a train of gears C, B and M connected by a link T. If the gears C, B and M have 60, 120 and 50 teeth, respectively, and C makes + 10 revolutions with respect to the link T, the gears B and M will make −5 and +12 revolutions, respectively, as shown in line (a), Table II, the positive signs denoting motion in the direction of the hands of a clock and the negative sign denoting counter-clockwise rotation.

TABLE II.—RELATIVE ANGULAR MOTIONS OF GEARS AND LINK SHOWN IN FIG. 4.

	T	C	B	M
(a).....	0	+10	−5	+12
(b).....	0	+ 1	− .5	+ 1.2
(c).....	−1	0	−1.5	+ .2
(d).....	+ .5	+ 1.5	0	+ 1.7
(e).....	−1.2	− .2	−1.7	0

(a) Angular velocities of the gears with respect to the link.
(b) Revolutions made by C, B and M when T is fixed and C turned through one revolution.
(c) Revolutions made by B and M with respect to C when C is fixed and T rotated left-handed through one revolution.
(d) Revolutions of T. C and M with respect to B when T is rotated.
(e) Revolutions of T. C and B with respect to M when T is rotated.

Dividing the values in line (a) by 10, gives the revolutions made by B and M per revolution of C, as shown in line (b). If the gear C is fixed and the link T rotated through one revolution around a as a center, the numbers of revolutions made by B and M are found by adding −1 to the values in line (b), and are given in line (c). Line (d) is obtained by adding 1.5 to line (c) or 0.5 to line (b), and shows the revolutions made by C and M when B is fixed and the link T rotated to the right through 0.5 of a revolution about the center b. For one positive revolution of T about b, C would make 3 and M 3.4 revolutions. Line (e) shows the relative velocities of T, C and a when M is fixed and T rotated about m.

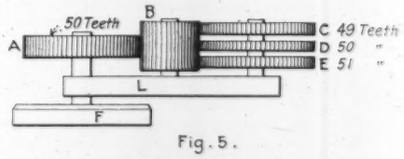


Fig. 5.
Ferguson's Paradox.

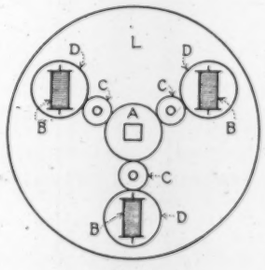


Fig. 6.
Cordelier or Rope Machine.

Figs. 5 and 6. Ferguson's Paradox and a Practical Application.

By inspection of Table I. and II., it is seen that the methods and results are identical. The relative motions of any three of the bodies with respect to the fourth has been determined without the use of a formula or complicated equations. Some of the advantages of this method of analysis may be stated as follows:

*Assistant Professor of Mechanical Engineering, University of Cincinnati, Cincinnati, Ohio.

(a) It involves no special formulas or rule which may be forgotten or misstated.

(b) The direction of rotation is easily found for the case in which all the gears rotate around fixed centers and for other cases the direction of motion of each member is denoted by the positive or negative sign.

(c) Problems may be solved in a shorter time and with less chance of error than by any other method.

This method was used by Professor Dunkerley, but whether or not the credit of its discovery is justly due to him, the writer is unable to state.

OTHER METHODS.—Text books give a general formula for epicyclic trains which is written

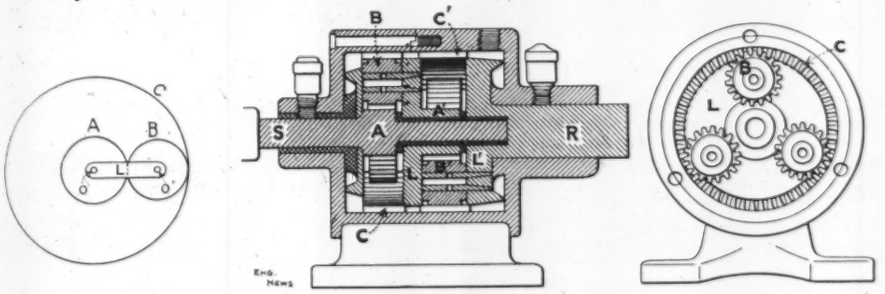
$$e = \frac{n-a}{m-a},$$

where, in a given length of time,

a = number of turns made by the link; m = number of turns by first wheel of the train; n = number of turns made by last wheel of the train; e = value of train, or ratio of the angular velocities, of the first and last wheels in the train, considering the link fixed.

The values of a, m and n are positive when they rotate to the right and negative when they rotate to the left. The value of e is considered positive when the extreme wheels rotate in the same direction and negative when they rotate in opposite directions.

An analysis known as the "lever method" which is based on the fact that the gears and link act instantaneously as a combination of levers, is often used. This method necessitates more thought than that shown in Tables I. and II. and may involve equations which offer more chance for error and require more time for solution.



FIGS. 9-10. THREE-GEAR ANNULAR TRAIN AND ITS APPLICATION IN THE O'KELLY SPEED REDUCING TRANSMISSION GEAR.

Ferguson's Paradox.

To show some of the peculiar results that may be obtained by the use of epicyclic trains and to illustrate their practical value the analysis of a few mechanisms involving planetary differential gears will be given briefly.

The mechanism known as Ferguson's Paradox consisting of the train of gears shown in Fig. 5 is an interesting example of the peculiar results that may be obtained by slight changes in the number of teeth on the gear M in Fig. 3. The wheel A is fixed to the base F. The link L rotates around the stem of F and carries the axles of B and of C, D and E. The velocities of the different parts, with respect to anyone that may be fixed, can be found from Table III., in which the letters denote the numbers of teeth on the respective gears. From this table, it is seen that if D is equal to A, a line on D will move parallel to itself when L is rotated. By having 50 teeth on A, 49 on C, 50 on D and 51 on E it is easily seen that one revolution of L will cause C to turn 1/49 of a revolution in the opposite direction to the link; D will not turn with respect to A, while E will make 1/51 of a revolution in the same direction as the link. When link L of this mechanism is rotated, it presents a rather peculiar appearance, since C is rotating in one direction, D not rotating, and E rotating in the opposite direction to C, while all three are in mesh with the same gear B.

TABLE III.—FERGUSON'S PARADOX.

Relative Angular Velocities.

A	B	C	D	E	L
1	$-\frac{A}{B}$	$+\frac{A}{C}$	$+\frac{A}{D}$	$+\frac{A}{E}$	0
0	$-\frac{A}{B}-1$	$+\frac{A}{C}-1$	$+\frac{A}{D}-1$	$+\frac{A}{E}-1$	-1

The Cordelier or Rope Machine.

The peculiar mechanism shown in Fig. 5 has no practical application as such, but the principles it involves are used in a rope-making machine called a "cordelier," which is shown diagramatically in Fig. 6. The gear A is fixed, and the axles of C and D are connected to a disk L which rotates around the center of A. The gears A and D have the same numbers of teeth, so that D does not rotate. The bobbins, B, carrying the strands or wires, are fixed to the gears D, and have, therefore, such a motion that the strands are not untwisted in laying the rope, although the twist due to laying is opposite to the twist in the strands. By making D slightly smaller than A, the strands will be given a slight twist in the opposite direction to that of the rope, causing it to lay tighter and be stiffer.

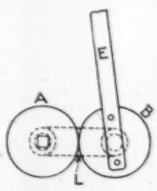


Fig. 7. Watt's Crank Substitute.

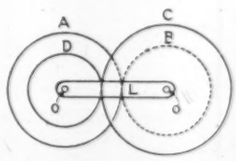


Fig. 8. Reverted Epicyclic Train.

Watt's Crank Substitute or Sun-and-Planet Motion.

While Watt was constructing his double-acting engine, James Pickard took out a patent on the crank and connecting-rod mechanism and Watt contented himself by inventing certain other mechanisms for obtaining a like result. Among these was the epicyclic train shown in Fig. 7. The gear A is fastened to the shaft and B, which is the same size as A, is held in mesh with A by the link L. The connecting-rod E is rigidly connected to B and has a pin connection with the working beam of the engine. This construction prevents the rotation of B, although it has a vibratory motion due to the angularity of the link E, but as this motion is periodic it has no effect on the number of complete revolutions.

TABLE IV.—WATT'S CRANK SUBSTITUTE.

Relative Angular Velocities.

B	A	L	
1	$-\frac{B}{A}$	0	L fixed.
0	$-\frac{B}{A}-1$	-1	B fixed and L rotated.

From Table IV. it is seen that if B and A have equal numbers of teeth, A will make two revolutions for each revolution of the link L, thus causing the shaft to rotate twice as fast as it would with an ordinary crank and connecting-rod, and an increase in the size of B with respect to A will increase the speed of the shaft.

Reverted Trains.

Fig. 8 shows a train in which the axles of the first and last gears are coincident, and is called a "reverted train." A and D are two independent gears on the pin O, or on different shafts. C and B are fastened together and rotate on the pin O'. By fixing either A or D and rotating the link around the center O, this combination forms an epicyclic train. The velocities of the different parts with respect to any one that may be fixed are given in Table V.

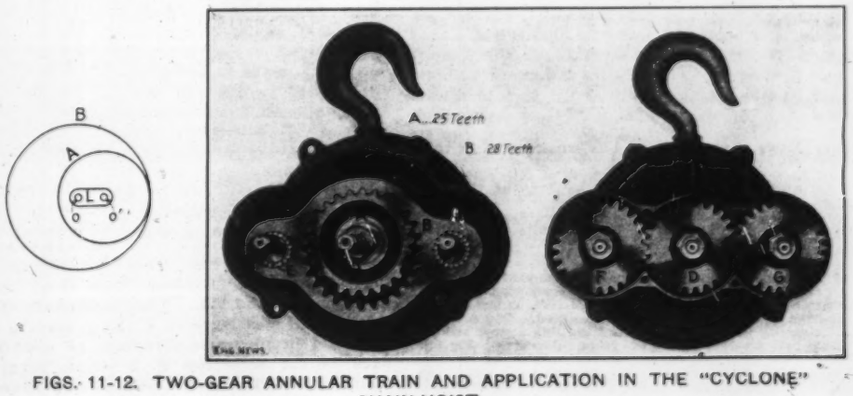
TABLE V.—REVERTED TRAIN.

Relative Angular Velocities.

A	B and C	D	L	
+1	$-\frac{A}{B}$	$+\frac{A}{B}\times\frac{C}{D}$	0	L fixed.
0	$-\frac{A}{B}-1$	$+\frac{A}{B}\times\frac{C}{D}-1$	-1	A fixed.
$1+\frac{A}{B}$	0	$+\frac{A}{B}\times\frac{C}{D}+\frac{A}{B}$	$+\frac{A}{B}$	B and C fixed.
$1-\frac{A}{B}\times\frac{C}{D}$	$-\frac{A}{B}-\frac{A}{B}\times\frac{C}{D}$	0	$-\frac{A}{B}\times\frac{C}{D}$	D fixed.

If the gear A is fixed and the link turned through one revolution to the left, D will make $\frac{A}{B}\times\frac{C}{D}-1$ revolutions. The direction in which D will rotate depends upon the value of $\frac{A}{B}\times\frac{C}{D}$. If $\frac{A}{B}\times\frac{C}{D}=1$, D will not move; if less than 1, D and the link L will rotate in the same direction and when greater than D, the motions of D and L will be in opposite directions.

To show the possibility of getting a high velocity with this mechanism, suppose the gears A, B, C and D have 99, 100, 101 and 100 teeth, respectively. Then for each revolution of the link, with A fixed, the gear D would make $\frac{99}{100}\times\frac{101}{100}-1=\frac{1}{10{,}000}$ of a revolution in the same direction; which means that link would have to make 10,000 revolutions to turn D through one revolution. This is a surprisingly high velocity ratio to be obtained from such a simple mechan-



FIGS. 11-12. TWO-GEAR ANNULAR TRAIN AND APPLICATION IN THE "CYCLONE" CHAIN HOIST.

ism, but the most interesting consideration is to suppose the gears A and D should be interchanged. This would change the velocity ratio to $\frac{1}{45.5}$ and cause D to turn in the opposite direction.

At first thought it would seem that reverted trains could be used for "reducing transmission gears" for motor drives, although if used for this purpose the linear velocity of the gears would be very high and it would be necessary to balance the weight of the revolving gears and the link.*

When C is fixed and L rotates around o as a center the velocity ratio of A to L is

$$\frac{1-\frac{A}{C}}{\frac{A}{C}} = \frac{C}{A} - 1.$$

An application of this case is found in the hoisting mechanism of the Shepard crane and in the O'Kelly "speed-reduction gear" shown in Fig. 10. Both have a compound epicyclic train. The pinion A, Fig. 10, is fixed to the high speed shaft S and meshes with three idlers B (three being required to maintain a satisfactory running balance) which are carried by pins on the disk L and mesh with the annular gear C fixed to the casing. The disk L is fixed to A' which is the pinion of the second train A', B', C' and drives the disk L' which is fixed to the low speed shaft R. If C has 57 teeth and A 18 the speed reduction is 4:1. This mechanism is also used for back gears on light machines such as drill presses.

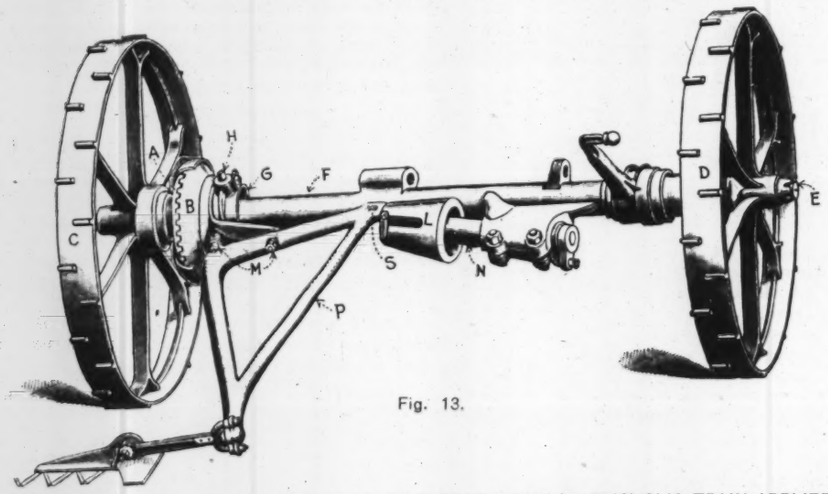


Fig. 13.

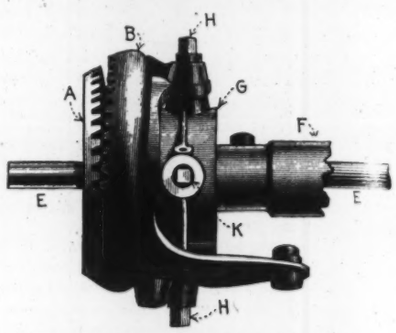


Fig. 14. Details of Gear Connection.

FIGS. 13-14. TWO-GEAR ANNULAR EPICYCLIC TRAIN APPLIED TO MOWING MACHINE.

Annular Trains.

In Fig. 9 the external gear A and the annular gear C are independent and loose on the pin O. The gear B meshes with A and C, and its center O' is connected with O by the link L.

TABLE VI.—THREE-GEAR ANNULAR TRAIN.
Relative Angular Velocities.

A	B	C	L	
+1	$-\frac{A}{B}$	$-\frac{A}{C}$	0	L fixed.
0	$-1-\frac{A}{B}$	$-1-\frac{A}{C}$	−1	A fixed.
$1+\frac{A}{B}$	0	$+\frac{A}{B}-\frac{A}{C}$	$+\frac{A}{B}$	B fixed.
$1+\frac{A}{C}$	$+\frac{A}{C}-\frac{A}{B}$	0	$+\frac{A}{C}$	C fixed.

By inspection of Table VI., it is seen that if A is fixed and L rotated, C will move in the same direction as the arm regardless of the relative numbers of teeth on the gears. The velocity of C is greater than the velocity of L and is increased by increasing A or decreasing B. The greatest value of $\frac{A}{C}$ is less than 1, hence the velocity ratio of C to L is always less than 2.

If the gear B is fixed and L rotated around o' as a center, the velocity ratio of C to L is

$$\frac{\frac{A}{B}-\frac{A}{C}}{\frac{A}{B}} = 1-\frac{A}{C}\times\frac{B}{A} = 1-\frac{B}{C}.$$

This shows that the gear A is superfluous in this case, and since B can never be greater than $\frac{C}{2}$ (unless A is discarded) the velocity ratio lies between ½ and 1.

When B is fixed and L makes one revolution A makes

$$\frac{1-\frac{A}{B}}{-\frac{A}{B}} = 1-\frac{B}{A} \text{ or } \frac{A-B}{A}$$

revolutions in the opposite direction. By making A almost as large as B this mechanism gives a high velocity ratio, but as A rotates around o' and revolves around o it is of little practical value in this form. It is possible, however, to change the form in such a way as to have A rotate around a fixed center without altering the kinematic relations. This has been accomplished in the design of the "Cyclone Chain Hoist" shown in Figs. 12 and 13. The hand-chain drives the wheel D meshing with F and G, causing them to rotate in the same direction. F and G are fixed to the eccentrics E E which impart an oscillatory motion to the yoke B and cause the gear A on the lift-wheel to rotate. In Fig. 11, the link L causes the center of A to move in a circle around o as a center with respect to B, whereas the eccentrics in Fig. 12 cause A to rotate around o' with respect to A, and thus by effect the same relative motion between A and B. It will be noticed, however, that the eccentrics must turn in the opposite direction to the link to effect the same result, and the value of $\frac{A}{B}$

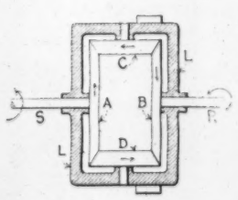


Fig. 15. Jack-in-the-Box Mechanism.

TABLE VII.—TWO-GEAR ANNULAR TRAIN.
Relative Angular Velocities.

A	B	L	
+1	$+\frac{A}{B}$	0	L fixed.
0	$+1-\frac{A}{B}$	−1	A fixed.
$1-\frac{A}{B}$	0	$-\frac{A}{B}$	B fixed.

In Fig. 12, A and B have 25 and 28 teeth respectively, and for each revolution of A, E makes

$$\frac{A}{B-A} = \frac{25}{28-25} = 8\tfrac{1}{3} \text{ revolutions.}$$

Figs. 14 and 15 show the application of an epicyclic train to a mowing machine. This machine was designed by Mr. Maurice Kane from the patents obtained by Rudolf Eickemeyer in 1870 and has maintained a record for satisfactory operation for more than a quarter of a century. The shaft E passes through the frame and is connected to the driving wheels C and D by ratchet couplings which cause the shaft to always rotate with the wheel having the greater velocity. The bevel gear A is keyed to the shaft E. The internal bevel gear B is pivoted to the gimbal ring G by two pins HH and the gimbal ring is similarly connected to the main frame F by two pins KK (only one shows in the illustrations) which are at right angles to HH and lie in the same vertical plane. The gear A is connected to a triangular frame P by bolts M.

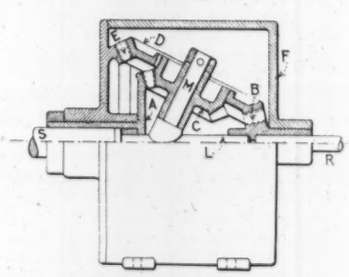


Fig. 16. Humpage's Gear.

*Reverted epicyclic trains have been used with fair success in "planetary" automobile transmisions, such as are often used on cars of about 12 HP., or less, where only two speeds and reverse are required. The problem of balancing is solved by making the link a disk and by using two or three sets of gears, B and C, Fig. 8. These gear pairs are equally spaced around the circumference of a circle, so that they balance each other. At the same time the load on the gear teeth is divided.—Ed.

Within the sleeve N is a shaft, the center line of which would cut the intersection of the axes of KK and HH if produced. Connected to this shaft is a hollow cone L which serves as a crank disk and receives a pin which fits in a bearing in the frame P at S. The center line of this crank pin would also go through the intersection of the axes of KK and HH if produced. Each point in the frame P and gear B is at a fixed distance from the point of intersection of KK and HH and any line (except HH or KK) from this point to any point on P or B will generate a conical surface. Points on the teeth of B describe small curves that are very nearly true circles; that they are not true circles is due to the fact that the axis of the crank shaft enclosed by N does not coincide with the axis of the shaft E or gear A. The motion of B with respect to A in Figs. 14 and 15 is very similar to the motion of B and A in the chain block shown in Fig. 12; the only difference being due to the use of bevel gears on the mover and spur gears on the chain block.

The gears A and B have 44 and 46 teeth respectively, so for one revolution of A, the crank makes $\frac{44}{46-44} = 22$ revolutions in the same direction.

Jack-in-the-Box Mechanism.

Fig. 16 shows what is known as the "jack-in-the-box" mechanism. It consists of two shafts S and R carrying two bevel gears A and B in mesh with C and D which ride loosely on pins mounted in the frame L.

TABLE VIII.—JACK-IN-THE-BOX MECHANISM.
Relative Angular Velocities.

A	B	L	
+1	$-\frac{A}{B} = -1$	0	L fixed
0	$-1-\frac{A}{B} = -2$	−1	A fixed

From Table VIII. it is seen that if K is fixed, A and B will rotate (in opposite directions) with the same velocity. When A is fixed, B makes two revolutions while L makes one in the same direction. This mechanism is used on a machine for crushing corn, A being fixed to the base and lower burr, B to the hopper and upper burr and a sweep which is drawn by a horse causes L to rotate, and the upper burr to make two revolutions for each revolution of the horse.

Another mechanism is obtained by this combination when A, B and L all move at the same time. By denoting the turns L makes by N_1 and adding it to the first line in Table VIII. shows that the velocities of A, B and L are respectively equal to $N_1 + 1$, $N_1 - 1$ and N_1. The sum of the velocities of A and B is $N_1 + 1 + N_1 - 1 = 2\,N_1$. Hence, the velocity of L is half the algebraic sum of the velocities of A and B and it will rotate in the direction of the gear having the greater velocity. This mechanism is used on the driving axle of automobiles and traction engines to allow the driving wheels to travel at different velocities when the machine is moving in a curve. It is also used in connection with a pair of cone pulleys to produce a differential motion for winding cotton roving (loosely twisted fibers) on bobbins. Another modification is used to detect the difference in speed between the star-board and port engines of a ship. It has also been applied to transmission dynamometers and governors.

Humpage's Gear.

Another application of an epicyclic train of bevel gears is found in "Humpage's gear" shown in Fig. 17. This mechanism has been used on lathes, capstans and electrical machinery where a high velocity ratio is required. The low-speed shaft S is keyed to a bevel gear A and the high-speed shaft R is keyed to the bevel gear B. The spindle M is fastened to a shaft L which is capable of rotating around the common axis of the shafts S and R. The gear C meshes with A and is fixed to the gear D which meshes with the gear E. C and D turn loosely on the spindle M, and are made in duplicate to obtain a balance. The gear E virtually forms a part of the fixed casing F which encloses the gearing.

TABLE IX.—HUMPAGE'S GEAR.
Relative Angular Velocities.

R	E and F	S	L and M	
+1	$-\frac{B}{E}$	$-\frac{B}{D}\times\frac{C}{A}$	0	L and M fixed.
$1+\frac{B}{E}$	0	$+\frac{B}{E}-\frac{B}{D}\times\frac{C}{A}$	$+\frac{B}{E}$	E and F fixed.

Table IX. shows that R makes $1+\frac{B}{E}$ revolutions while S makes $\frac{B}{E}-\frac{B}{D}\times\frac{C}{A}$ revolutions; hence, for one revolution of S, R makes

$$\frac{1+\frac{B}{E}}{\frac{B}{E}-\frac{B}{D}\times\frac{C}{A}} = \frac{D\,A\,(E+B)}{B\,(D\,A - C\,E)}$$

By making the numbers of teeth on A, B, C, D and E respectively equal to 48, 16, 24, 64 and 80, the speed may be increased or decreased in the ratio of 16 to 1.

The Clinkering of Coal: Results of Tests for Effect of Various Constituents in the Ash.

By LIONEL S. MARKS,* M. Am. Soc. M. E.

Our present-day knowledge of the causes of clinkering of coal and of the methods for its prevention or reduction is almost entirely the result of general experience rather than of special experiment. There is a widespread belief that the sulphur in coal is the principal cause of clinkering and of the rapid eating away of the fire-bars by which it is often accompanied. It is well known that a bar of red-hot iron will melt where it is put in contact with a cake of sulphur, and this is commonly accepted as an adequate explanation of the wasting of the fire-bars during clinkering. It is also generally believed that iron in coal will cause clinkering; although when this iron occurs as pyrites, it is difficult to distinguish between the actions of the iron and of the sulphur. An iron bolt or nut which gets into the coal by accident is found to give much trouble in a furnace, particularly on stepgrates, where it may cause the melting or burning-away of a considerable part of a step, and give rise to a strongly adhesive local clinker.

The principal remedy for clinkering in bad cases, it is generally known, is a steam-jet in the ash-pit directed against the grates; for less troublesome cases the use of water in the ash pit. In general, low-temperature combustion is recognized as desirable wherever there is a decided tendency towards the production of clinker. In domestic stoves the old remedy against the formation of clinker, or its adhesion to the fire-brick lining, is the occasional addition to the fire of a few oyster shells—and there is ample testimony that it answers well.

This general knowledge, the result of general experience, is satisfactory as far as it goes; but it does not meet the demands of modern coal-furnace practice. The attention of the writer was drawn particularly to this subject in the course of a series of boiler-tests on which he was engaged at a large modern steam-plant. The progress of the tests was materially interfered with by unexplainable variations in the behavior of the coal. All the coal was taken from the same coal-pile; but one day, during the repetition of a test under unchanged conditions, it was found that the fire clinkered badly, so that the combustion was less perfect, the fire had to be cleaned at shorter intervals, and the efficiency fell off about 8%. The proximate analysis of the coal showed no change in composition, in ash content, or in sulphur. A determination of the fusing temperatures of the ash showed lower fusing temperature, but the clinker had the same fusing temperature as the clinker from the previous tests. Further experience emphasized the need for some thorough investigation of clinkering. The investigations which are recorded here, give, in general, rather negative results; but they may be of interest in view of the lack of data in this important field.

The objection to clinkering is mainly economic: it increases the cost of the heat liberated from the coal (1) by decreasing the efficiency and capacity of the furnace, (2) by increasing the labor cost, and (3) by shortening the life of the fire-bars and of the fire-brick lining. Occasionally it may interrupt entirely the operation of an industrial plant, as when a badly clinkering batch of coal, used on a chain grate or other moving grate, clogs up the moving parts entirely.

From the point of view of the coal user, there are two principal methods of reducing the economic loss which results from the clinkering of coal. The first is by drawing up coal specifications in such a way as to penalize a clinkering coal in proportion to the losses that it will cause. But this requires that the user should have available such information as will enable him to determine, by practicable tests on a sample of the coal, what will be the behavior of the coal in the actual furnace. This information is not at present available; the possibility of obtaining it is discussed later in this article. The second method is by reducing the clinkering which results from the normal combustion of any given coal. The principal object of the investigations detailed here was to discover, if possible, the conditions under which the combustion could be carried out either with diminished clinkering or with the clinker so modified and controlled as to give less trouble.

The Composition of Coal and Ash.

Coal consists of fixed carbon, hydrocarbons, water, oxygen, nitrogen, sulphur and ash. Clinkers result from the fusing of the ash. For a given temperature of the fire, it is presumably true that the amount of clinkering depends on the composition and amount of the incombustible residue, and also probably on the amount of sulphur present. That is, it seems permissible to disregard the carbon, hydrogen, oxygen and nitrogen, except in so far as their relative or absolute amounts may determine the temperature of the fire. It must, however, be borne in mind that the caking of the coal, which is determined principally by the hydrocarbons, may have considerable influence on clinkering.

The incombustible matter which may be present in coal may be divided into four classes according to its origin, as follows:

(1). Ash originally in the wood from which the coal is derived. The ash in present-day woods amounts, as a maximum, from 1 to 1½% of the weight of carbon in the wood. Since some of this carbon is volatile, that is, is combined with hydrogen and may escape during the process of changing wood into coal, it is proper to expect that, at the outset, the original ash in coal will not exceed 1½ to 2% of the carbon of the coal, or say, 1 to 1½% of the total weight of the coal. Generally, the original ash may be expected to be less than this amount. The potash and soda salts in the original ash are highly soluble and may in many cases have been leached out. The soluble salts amount to from 20 to 40% of the original ash. The remaining 60 to 80% consisting of 20 to 30% carbonate of lime, 12 to 18% magnesia, 10 to 15% phosphates, and 18 to 30% of silicic acid, will always remain in the coal.

In general, then, we may expect a coal to contain some of the original ash of the wood to the extent of from 1 to 1½% of the weight of the coal. This gives on the average 0.3% carbonate of lime, 0.2% magnesia, 0.15% phosphates, and 0.3% of silicic acid.

*Harvard University, Cambridge, Mass.

Name of coal.	Locality.	Percentage of ash in coal.	Percentage composition of ash.					
			Al_2O_3	CaO	Fe_2O_3	MgO	SiO_2	SO_3
Buck Mt. Anthracite	Pa.	7.26	27.03	1.56	42.87	1.83	25.66	.17
Morris Run	Pa.	10.35	35.34	1.55	1.78	.04	60.93	.28
Pardee	Pa.	3.14	45.20	3.14	1.23	.10	44.28	.78
Laceyville	Ill.	5.04	16.94	11.22	38.52	....	28.43	3.79
Ohio Coal Co.	Ohio	11.04	22.79	10.67	10.72	....	51.37	2.48

(2). The deposits of wood from which coal is formed apparently took place in lagoons or low marshy ground liable to occasional floods, resulting in the bringing down of silt which deposited itself with the fallen wood. The thin lamellae which occur throughout many coals are presumably of such origin. The composition of these thin layers is naturally extremely variable according to the material brought down by the rivers; it is generally argillaceous and siliceous. This material, since it cannot be separated from the rest of the coal either in firing or in sampling, must be considered as part of the true ash of the coal. It is obvious that its presence is likely to cause considerable variation in both the amount and composition of the ash in different parts of any seam of coal. The greater part of the ash in ordinary clean coals may be ascribed to this origin.

Besides the mineral matter which was thus deposited with the wood in the solid state, there were salts in solution which have been precipitated in the wood and which in some cases have replaced the soluble constituents of the wood ash. Certain calcium salts and silicates have been added in this manner. It is highly probable that most of the sulphur in coals entered in solution as calcium sulphate and was slowly reduced by the organic matter to the sulphide. It is also probable that the iron pyrites which is so often intimately associated with coal, has a similar origin.

(3). When the coal comes from near the walls of a seam, and when the mining is not carefully done, there is likely to be present, mixed with the coal, a certain amount of the material of the walls. This material cannot properly be regarded as true ash of the coal—it is simply impurity which results from unsatisfactory methods at the mine. Such foreign matter may be calcareous, argillaceous or siliceous. Its amount should be small in any carefully mined coal, but a small amount of it may, under certain circumstances, be highly deleterious.

(4). In transit from the mine to the furnace there is sometimes the accidental addition of foreign matter to the coal. A stray iron bolt or nut gets in occasionally—or some of the ground of the coal yard may be scraped up. These additions may lead to occasional troubles.

The coal from any given source may form clinkers under normal conditions of operation, or only exceptionally. If it clinkers always, it may be assumed that the clinkering results from the presence of the true ash (varieties 1 and 2); if it is only occasional, it will be due either to a higher temperature than usual or other change in the conditions, or else to the presence of impurities of varieties 3 and 4. With normal clinkering there is no difficulty in obtaining a fair sample of the ash which is giving the trouble; with the occasional clinkering due to the presence of impurities it is practically impossible to get a fair sample since these impurities are not distributed throughout the mass. The detection of the causes of occasional clinkering from the analysis of the coal is consequently very difficult.

THE COMPOSITION OF COAL ASH.—Certain attempts have been made to relate the clinkering of coal to the chemical composition of the ash. With the object of finding whether there are any general characteristics of coal ash, the literature on the subject has been searched for all the available chemical analyses in all parts of the world. A thorough examination of the data collected fails to reveal anything that may be regarded as a general characteristic of coal ash, as distinguished from ordinary rock substance. The number of constituents is always large and the variation in the percentage present of the various constituents is extreme.

The following analyses selected from a small number reported by Pennock* indicate the variation that is found in the ash from one general locality.

With this enormous variation in the composition of the ash it seems hopeless to expect that any set of investigations of practicable extent could clear up the relation between the composition and the clinkering of ash.

*Trans. Am. I. Min. Eng. Vol. 21, 1893.

Fusibility and Viscosity of Ash.

Clinkering is a result of fusion and is some function of the fusibility of the ash. But it is impossible to consider fusion without taking viscosity into account. The fusing temperature of an ash is not necessarily—is not generally—a single-valued temperature. At some particular temperature, some one constituent of the ash will melt; if it is a minor constituent the effect may be that the ash becomes a very viscous pasty mass. At higher temperatures other constituents may melt and the mass will become more liquid. In other cases, the ash may become liquid as soon as the initial melting temperature is passed. It is evident that the viscosity of the melt will have an extremely important influence on clinkering. If the melt is very viscous, we shall get a sticky mass which will attach to itself the surrounding coal and ash and form a troublesome clinker; if it is more fluid it will run on the grate bars and will in part freeze there and may be difficult to detach; if it is extremely fluid and melts at a temperature very much below that of the fire, it might possibly flow from the fire like water and give very little trouble.

There is in existence some information as to the fusing temperatures of ash materials of various compositions, but this information would have to be enormously extended before it became useful for the study of clinkering. Moreover, even if such information were fully available, it would necessitate the tedious and costly analysis of the ash before it could be applied; and even then in the absence of exact knowledge as to the temperatures that would be reached in the fire, it would not be possible to foretell the behavior of the ash in an actual furnace. The very important question of viscosity is practically uninvestigated. Consequently, it appears that it is now, and probably always will be, quite impracticable to approach the subject of clinkering from the analytical side; and, that little is to be gained from ash analysis unless it can be shown that certain fluxes are present in considerable amount.

THE FUSIBILITY OF VARIOUS ASH CONSTITUENTS.—The present knowledge and theories as to the formation of clinkers may be divided into certain facts which may be accepted, and certain theories more or less supported by experiment or experience.

The chemical compounds which are present in ash are principally the oxides of aluminium (Al_2O_3), of silica (SiO_2), of iron (FeO or Fe_2O_3), of lime (CaO), of potash (K_2O), of magnesium (MgO), of sodium (Na_2O), of sulphur (SO_3), and to a lesser degree of manganese, phosphorus, zinc, lead and other elements. A careful chemical analysis will disclose the weights of these constituents but will in general fail to show how they are combined with one another. The silica, for example, is probably present in the form of silicates of aluminum, iron, lime and other elements; the sulphur as sulphides of iron or sulphates of magnesium or other elements. The exact method in which these substances are combined is certainly of importance in connection with fusibilities, but it is not determinable.

Certain facts can be postulated as to the behavior of these various substances at high temperatures. Alumina (Al_2O_3) is the most infusible, melting at a temperature higher than 1900°C; silica is the next in order of fusibility and melts at about 1430°C. A mixture of alumina and silica melts at some temperature intermediate between 1430 and 1900°C, the temperature falling as the percentage of silica increases. One part of alumina with five parts of silica melts at 1750°C; one part of alumina with ten parts of silica at 1690°C. It appears then, that the presence of a comparatively small amount of alumina has a considerable influence in raising the temperature of fusion of silica.

The temperature in a boiler furnace is probably never greater than 1,600° to 1,750° C.—usually it is considerably less. It is obvious then, that a mixture of alumina and silica will be infusible in a boiler furnace so long as a minimum of 10% of alumina is present. But there is very little coal ash with as little as 10% of alumina. The usual amount of alumina is from 20 to 40%.

The iron, lime, potash, soda, magnesium and other compounds that are present, may be regarded as fluxes, tending to reduce the melting point of the alumina-silica mixture. When the constituents are mixed in such proportions as to give the lowest fusing temperature, we have what is called the "eutectic" mixture. The fusing temperature of the eutectic mixture may be below the fusing temperature of the constituents. It is sometimes several hundred degrees low in mixtures of ash materials. Sodium silicate melts at about 1000°C; calcium silicate at about 1350°C; the eutectic mixture of the two contains about 20% of calcium silicate and melts at about 940°C; with 80% of calcium silicate the melting temperature is about 1130°C.

The reduction in the melting temperature of alumina and silica, or their compounds, resulting from the presence of the oxides, silicates, sulphates, sulphides or other salts of iron, lime, potash, soda, magnesium, or other commonly occuring elements, may be very considerable. The actual reductions in melting temperature vary greatly with the different substances. The presence of FeO brings about a much greater reduction than that of CaO, but the presence of both in the eutectic proportions will always bring about the maximum reduction. Thus a mixture of 45% of SiO_2 with 55% FeO melts at 1120°C; with 10% CaO substituted for FeO, we get the eutectic melting at 1060°C; with 45% of CaO substituted for FeO, the melting temperature rises to about 1350°C. Similarly, the presence of CaO brings about a greater reduction of melting temperature than that of Al_2O_3. A mixture of 32% SiO_2, 36% FeO and 32% CaO melts at 1150°C; with 5% of the CaO replaced by Al_2O_3 we get the eutectic, melting at 1110°C; with all the CaO replaced by Al_2O_3 the melting temperature is raised to 1350°C or higher.

The effect of adding SiO_2 to a mixture of two parts FeO and one part CaO melting at 1190°C, is first to decrease the melting temperature to 1110°C at the eutectic proportions (52% SiO_2 32% FeO, 16% CaO) and then as more SiO_2 is added to increase the melting temperature rapidly to over 1300°C when the SiO_2 reaches 60%.

It is probable that an ash will not give trouble by clinkering under usual furnace conditions when the fusing temperature is above 1500°C (2700°F. approximately) and that the trouble experienced will increase as the melting temperature falls below this temperature, for a range of several hundred degrees. The investigations of Hoffman show that for mixtures of CaO, FeO and SiO_2 it is only when the CaO is about 50% of the whole that the fusing temperature is as high as 1500°C and that a comparatively small decrease in the CaO (of say 10%) is usually sufficient to drop the melting temperature 200 or 300° C. Potassium and sodium salts are particularly active in lowering the melting temperatures but they appear seldom to be present to any noteworthy degree,—that is, exceeding 1%. Lime is usually from 2 to 10% of the ash; alumina 15 to 50%; silica 25 to 60%; Fe_2O_3 5 to 50%; MgO from 1 to 4%; and other substances in smaller amounts.

PROST'S FORMULA.—Notwithstanding the very great (and but superficially known) variation of the melting temperature of ash materials with their composition, an attempt has been made by Prost* to connect them by a formula. Prost does not give anywhere the experiments on which his conclusions are based, nor does he indicate the extent of his researches. He gives merely his summing up of his results in a formula. He finds that for slags in which the only important constituents are Al_2O_3, SiO_2, Fe_2O_3, CaO and MgO, the temperature of fusion increases with the increase of the content of Al_2O_3 and decreases with the increase of the other constituents. If Oa, Os, Of, Oc and Om represent the quantities of oxygen combined in the oxides of Al, Si, Fe, Ca and Mg respectively, then the fusing temperature is a function of $\frac{(Oa)^2}{Os \times (Of + Oc + Om)}$

If this quantity or modulus exceeds 3, the us-

*Manual of Chemical Analysis.

ing temperature exceeds 1500°C; if it is less than 1, the fusing temperature is below 1300°C; and, in general, the fusing temperature falls as the value of the expression decreases.

No attempt has been made by F. P. Sparrow to apply Prost's methods to coal ash. At the last meeting of the Association of Edison Illuminating Companies, he gave 19 analyses of the ash of coals burned commercially, and he stated that the trouble from clinker formed is in proportion to the value of Prost's modulus when its value is below 2.47. (Presumably he means inversely proportional.) This should be very valuable confirmation of Prost's results, but in the absence of more definite information, it can scarcely be accepted as final.

There are various reasons why Prost's formula should not be accepted. An examination of the available literature for reliable determinations of fusing temperatures of mixtures of Al_2O_3, SiO_2, Fe_2O_3, CaO and MgO shows that there is practically nothing available for temperatures much above 1300°C. Some good determinations by Hoffman yield the following results:—

Prost's modulus.	Fusing temperature.
.9	1,290° C.
.445	1,220° C.
.424	1,310° C.
.406	1,300° C.

These quantities do not bear out his theory, as the fusing temperatures do not decrease regularly as the modulus decreases. This formula was devised, moreover, for slags, that is, for matter in an amorphous state. In the case of coal, we have some of the ash in a crystalline state, and consequently with a different fusing temperature. Further, the fusing temperature is not always a definite temperature but may cover a considerable range of temperatures. The trouble from clinkers also depends on the viscosity of the melt, which is not a function of melting temperatures. Ash may contain other constituents than those which the formula takes into account; constituents which may have an important influence on melting temperatures. Finally the experiments of the writer, to be described later, do not support Prost's theory.

In view of these facts it seems unsafe to rely upon Prost's method. The general idea contained therein is undoubtedly sound, namely, that the temperature of fusion is increased by increasing the alumina and is decreased by substitution for alumina of other constituents; but in the present state of knowledge it is impossible to tell from a chemical analysis what will be the fusing temperature and how much trouble will arise from clinkers. As the chemical analysis is difficult and expensive, it is perhaps not entirely regrettable that Prost's method should not be used. It is at least as cheap and as easy, and certainly more satisfactory to burn the coal on the grate to determine the amount of clinkering.

The Influence of Sulphur.

A very common view as to clinkering is that it is due to (or accompanies) sulphur in coal. For example, Cunningham, in the Journal of the American Society of Naval Engineers, says:

> The other general effect of sulphur is to form clinker. It is a safe general proposition that the higher the sulphur, the higher will be the ash, slate and other inert matter, and under the effect of heat, clinkers will form which will kill the drafts and more or less injure grate bars and linings.

A more discriminating statement of the case results from the experience of the U. S. Geological Survey.* In summing up the results of four hundred boiler tests the following remarks occur:

> It is agreed that clinkering is a consequence of the effect of high fuel-bed temperature on such of the mineral constituents in the ash as will form a fusible mixture. It must be remembered that the fineness of subdivision and the distribution of the mineral throughout the coal are probably as important as the temperature and chemical composition. Thus it is that "sulphur" (pyrites) in the form of little balls is nearly harmless; in the form of veins or layers it is likely to cause trouble; but in the form of "black sulphur" so finely distributed as to be invisible, it is most troublesome.

The curve which accompanies this discussion shows that when the sulphur present exceeds 2%, the percentage of clinker in the refuse increases with the sulphur content. The remark, however, is made, "It must be borne in mind that perhaps sulphur of itself has little to do with fusibility of ash, and that the iron which is combined with a part of the sulphur is only one of the factors in clinkering."

The influence of sulphur is undoubtedly considerable in some cases, but the clinkering depends on the percentage of sulphur in the ash, rather than the percentage of sulphur in the coal. High sulphur is commonly accompanied by high ash, and the sulphur is not then necessarily very troublesome. As much as 5½% sulphur may exist in a coal without causing clinkering. This is probably due to the fact that the temperature of the furnace is likely to be low when the percentage of ash is high. When, however, the percentage of sulphur in the ash is high, much clinkering is likely to result. The effects of sulphur are well set forth as follows in the report of the U. S. Geological Survey:*

> Sulphur is an undesirable element in coal. It generally occurs in combination with iron, as iron pyrites, and in combination with calcium, as calcium sulphate or gypsum. Pyrites can readily be recognized by its heavy weight, bright brass-like color, and crystalline structure. The calcium sulphate occurs in small, thin, white flakes, more or less transparent. Of the two sulphur compounds, the pyrites is generally in larger quantity in coal, and is harmful because it increases the tendency of the coal to clinker. The clinkering is especially bad if the percentage of ash is small in proportion to the sulphur. In such coals, the pyrites and the ash fuse together and form a thin layer of solid clinker, which effectively stops the passage of air through the grate, thereby permitting the grate bars to become heated from the hot fuel bed just above. The clinker then melts down into the spaces between the bars and the sulphur seems to combine with the iron of the grate. The heat warps the grate bars, and the clinker has such corrosive action on the hot iron that a set of grate bars is destroyed in the course of a few days. When such clinkering occurs, any attempt to slice the fire fails, and only slow and very difficult cleaning of the fires will remove the clinkers.

The Influence of Iron.

Another common view as to clinkering is that it is caused by iron. This has already been discussed above incidentally. The presence of iron certainly results in a lowering of the melting temperature—and so far as the presence of iron means the presence of sulphur, there may

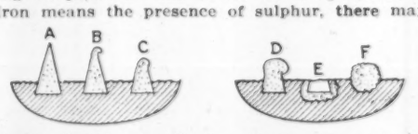


Fig. 1. Ash Cones for Investigating Fusibility of Coal Ash.

be that secondary reason for clinkering. The tests of the U. S. Geological Survey show a decided increase in the percentage of clinker in the refuse, as the percentage of iron in the coal increases.

It may be noted that the melting temperature of pure iron is about 1600°C; and that the eutectic mixture with carbon contains 4.3% of carbon and melts at 1130° C. There do not appear to be any reliable figures for the heat of combination of iron with carbon so that it is not possible to say whether this combination will be accompanied by the evolution of much heat. An iron bolt raised to a temperature of about 1600°C. in the fire will melt and will combine with some of the surrounding carbon and sulphur. The molten compound may contain more carbon than the eutectic mixture and may be at a temperature considerably above its own melting point. On coming into contact with a cast iron fire-bar (containing 2 to 3% of carbon and melting at 1200° to 1300°C), the molten compound will not only heat part of the fire-bar above its melting temperature, but may also give up some of its excess carbon to it, thereby lowering the fusing temperature of the bars to some value nearer the eutectic temperature of 1130°C.

It is probable that the fire-bars waste away, wherever contact takes place with molten iron or with ordinary molten clinker, in two ways: (1) by direct melting and, (2) by chemical combination or solution. The latter is undoubtedly the more active agent since the chemical combination or solution will in general result in a lowering of the melting temperature of the cast iron and may be accompanied by evolution of heat.

The size of coal has apparently no effect on clinkering. It might be thought that with larger lumps of coal the heavy ash would be kept in the hotter zone of the fire and would not be so free to fall by gravity nearer to the grate. No variations, however, can be detected in the formation of clinker when the size of the coal is changed.

Possible Methods for Preventing Clinkers.

From the foregoing it would appear that it is impracticable to foretell, from chemical analyses, the degree of clinkering which is likely to result from the burning of a given coal under some given boiler. The main interest of this enquiry must then be the search for some means of preventing or reducing clinkering, or failing in this, means of preventing or reducing the loss of efficiency of combustion which results from clinkering. There seem to be several possible courses to pursue:

(1). Reducing the temperature of combustion in the furnace will reduce or prevent clinkering. This can be accomplished by sending more air through the fire, but it will always be accompanied by a reduction in efficiency. Badly clinkering coals should be burned at low temperatures as the reduction in efficiency from a large excess of air will not usually be so important as the losses from bad clinkering.

(2). For coals high in ash, the use of steam blown in from below the grate will prevent the clinkers freezing on the grate, and consequently will save labor and the deterioration of the grate, and will permit longer periods of operation between cleanings of the fire. The steam is decomposed by the grate and the clinker, and not only prevents the clinker freezing on the grate, but also tends to break the clinker into smaller masses. With some clinkers this method is not found to give much relief. The use of steam in this way should not result in any considerable reduction in efficiency.

(3). The fusing temperature or viscosity of the ash might be raised by mixing certain substances with the coal so as to prevent either the fusing of the ash or the flow after fusing.

(4). The fusing temperature and viscosity might be so much reduced by the admixture of various fluxes, that the fused material would run through the grates like water without freezing on them.

The operation of remedies (1) and (2) is well known and needs no particular investigation. Remedies (3) and (4) have apparently not been tried at all, or only sporadically; and consequently the investigations recorded here were directed entirely along those lines. These investigations were of two kinds, (a) with the ash alone and (b) with coal burning on a stationary grate.

Investigations of Fusibility of Ash.

For the investigation of the ash alone, samples of coal were burned slowly at a low temperature so as to obtain a completely unfused ash. The ash was then moistened with a 10% solution of dextrin, and was moulded into pyramids of the standard form and dimensions of the Seger cone (Fig. 1, A). Other cones were made of intimate mixtures of the coal ash with known proportions of various mineral substances. The cones were then slowly heated in a gas muffle where they could be kept under occasional inspection, to observe their behavior. The temperatures were observed by means of a Le Chatelier thermo-electric pyrometer. Records were kept of the temperatures of beginning of fusion (Fig. 1, B) and sketches were made of the cones as they melted down, the corresponding temperatures being noted. In this way a body of information was collected as to the effect on both fusing temperature and on viscosity of the admixture of various substances. The viscosity could be very readily judged by the behavior of the cone. In some cases the cone melted to a fluid of the viscosity of water (Fig. 1, E); in other cases it formed a spongy, viscous mass (Fig. 1, F). The importance of this difference in behavior in a furnace is obvious.

A standard coal ash (from West Virginia coal) of which no analysis was made, was used in most of these tests. It was the ash from a coal which burned very well in a furnace where the temperature was from 1500° to 1550°C., and gave practically no trouble from clinker. The

*Bulletin No. 325, p. 28.

*Bulletin No. 325.

coal contained about 6% of ash and 1% of sulphur. This standard ash started to fuse at a temperature of 1370°C, and the cone was half melted down at 1400°C (Fig. 1, C).

The addition of alumina caused a rise of the fusion temperature. With 33% of Al_2O_3 added, the first indication of fusion was at 1400°C. With higher percentages of Al_2O_3, no sign of fusion could be perceived at 1400°C, which was the highest temperature available.

The addition of lime $Ca(OH)_2$ in moderate amount, lowered the fusion temperature considerably, an addition of 33% causing the complete fusion of the ash to a thin fluid at about 1250°C. With 100% of lime added, the fusing temperature exceeded that of the original ash.

Oxide of iron (Fe_2O_3) reduced the temperature of fusion but slightly. With 25% added, the cone is completely gone at 1380°C; with 50% it is nearly completely fused at 1390°C; with 75% it is three-fourths fused at 1390°C. The fused mass is but moderately liquid at the temperatures stated.

The effect of the addition of Pyrites (FeS_2) is more marked. With 25 to 75% added, the cones begin fusing at about 1200°C, the melting temperature being lower the greater the amount of pyrites present. The cone swells into a pasty mass (Fig. 1, F.) which remains viscous even at temperatures above 1365°C.

The effect of the presence of iron filings thoroughly mixed with the ash is to reduce the fusion temperature somewhat for moderate amounts. With 25% of iron added, melting begins at about 1320°C, and the cone is half melted at 1360°C. With larger percentages of iron the fusion temperature is much less affected. With 50% of iron, for example, there is incipient fusion at about 1360°C.

Calcium sulphide (CaS_2) has a marked effect in reducing fusion temperatures, the effect being greater the larger the amount of it present. With 50% or more, the fusion begins at a temperature slightly over 1200°C, and the melt is extremely liquid, so that at 1220° or 1230°C, the cone disappears entirely (Fig. 1, E). With 25% of CaS_2, the cone is half-melted at about 1300°C.

Calcium sulphate has a very similar effect. The addition of 50% causes incipient fusion at about 1250°C, and complete fusion at about 1300°C, while 75% causes complete fusion at about 1250°C. The melt is extremely fluid.

A similar series of investigations was made on the ash of another coal from West Virginia which had given some trouble by clinkering, in the fire. The results with this second ash were practically identical with those described above.

The investigations show, that if an intimate mixture is made of the ash from a typical West Virginia coal with various other substances, the results to be expected are as given in the accompanying table of melting temperatures.

From the above it is evident that the sulphides of iron and of lime have much more effect than the oxides in reducing temperatures of fusion; that is, that sulphur is harmful when it is present in these forms and that iron and lime are objectionable in small quantity but less so in larger quantity.

Whether these conclusions are applicable to an ash in which the foreign substances are actually combined in the above proportions, instead of being mechanically mixed, is not shown by the above, but it is presumable that the general conclusions are applicable. Whether these conclusions are applicable to other ashes is another moot point. Since they deal only with considerable admixtures, the writer is inclined to think that the conclusions could be pretty generally applied.

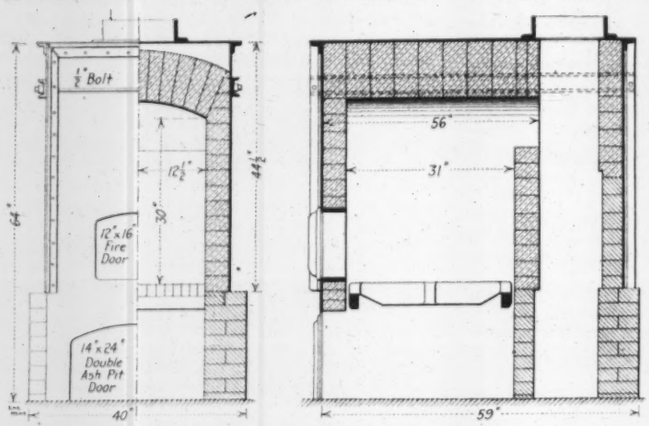


FIG. 2. SPECIAL FURNACE FOR INVESTIGATION OF EFFECT ON CLINKER OF MIXING VARIOUS SUBSTANCES WITH THE COAL.

Investigations of Clinkering of Coal.

The investigations described above are to be regarded as preliminary only, and were made for the purpose of indicating what should be mixed with a coal that is being fed to a furnace in order to reduce the clinkering trouble. The next set of investigations had as its object the direct determination of the effect of the addition of foreign substance in the furnace. For this purpose, a special furnace was built, Fig. 2, with a grate area of 5 sq. ft. The furnace is of steel, lined with firebrick, and is so designed that the gases are not subjected to any cooling influence until after they have left the furnace. The grate consists of stationary cast-iron bars of usual design. The temperature above the fire was measured continuously by a thermo-electric couple, the leads from which were protected by a water-jacketed pipe. Flue-gas samples were taken continuously through a water-jacketed sampling tube. The rate of combustion was maintained constant in all tests at 20 lbs. per sq. ft. of grate per hour. Coal was fired in uniform amounts at ten-minute intervals.

Each test lasted five hours, after which time the fire was permitted to burn out. The ash on the grate and in the ash pit was then weighed and the clinker was picked out from the ash and weighed separately. All the tests were made with the same coal, a West Virginia coal, which gave but moderate clinker. The fire was started for each test with plain coal. An intimate mixture of the foreign substance and the coal in the desired proportions was made on an iron plate and this mixture was fed after the fire was once fully started. The desired rate of combustion was maintained by regulating the opening of the ash-pit door. The fire door was usually opened once between firings, for slicing or leveling.

For the purposes of comparison with the kind of clinker formed by the coal used in these tests, two well-known coals, Pocahontas and George's Creek, were also burned under prec'sely similar conditions. The results of the tests were as follows:

Kind of coal.	Weight of ash. %	Weight of clinker. %	Remarks.
Pocahontas.....	6.0	4.4	Free burning, little slicing, low draft required, light porous clinker giving very little trouble.
George's Creek.....	9.2	3.8	Free burning, clinker very porous and brittle; very little trouble.
Test coal..... (W. Virginia)	7.4	3.4	Clinker somewhat more solid and troublesome than for other coals.

The ash and clinker in this table and [illegible] that follows are expressed as a percentage of the [illegible] weight of substance fired onto the grate. In the test coal, the ash averaged 6%, and this was assumed to be the ash content in determining the weights of foreign substance to be used in the various tests. The weight of such foreign substance is expressed hereafter as a percentage of the weight of ash assumed to be present. As the weight of ash is assumed to be 6 lbs. per hundredweight of coal, the addition of 3 lbs. of foreign substance per hundredweight of coal is written down as 50%, indicating that the weight of the substance added is 50% of the weight of the ash.

The first substance added was kaolin. Kaolin is the purest form of clay; that is, it is the clay containing the largest percentage of aluminum silicate and the smallest percentage of free quartz or silica. The average composition is 47% silica, 39% alumina, 14% water and a little iron and magnesia. It was used for the purpose of determining what effect the addition of the purest kind of clay would have on the fire. The most refractory fire clays contain considerably less alumina and much more silica than kaolin and consequently melt at a lower temperature. Their average composition is 65% silica, 28% alumina, 5% ferric oxide. The kaolin was thoroughly pulverized and was mixed with the coal in the proportions of 25%, 50% and 75% in three separate tests. The effect of the addition of kaolin was to decrease the clinker trouble, the benefit increasing steadily as the percentage of kaolin was increased. The clinker adhered less to the grates and became more puffy, slicing was easier and the fire burned more freely but with some tendency to cake.

The effect of the addition of pure silica was tried by adding crushed white quartz in the form of small grains of a size to pass through a sieve with 900 holes to the square inch. This was tried in three proportions, 25%, 50% and 100% of quartz, respectively, being added. The clinker did not adhere at all but formed in large masses high in the fire. It was very porous and brittle. The quartz apparently did not fuse but was everywhere present as white grains in the clinker. The fire burned very freely, and with the highest percentage of quartz, gave very high furnace temperatures. The effect of the quartz was apparently beneficial in all respects.

Crushed quartz is too expensive a material to recommend for general use; the commercial material nearest to it is ordinary sea sand, which consists mainly of quartz grains mixed with various other material. The effect of the addition of 100% of ordinary yellow sea sand was tried and was found to be entirely bad. The quartz grains remained as before unchanged, but the other constituents acted as a flux and gave a very hard clinker which lay close to the grate and hindered the operation of the fire considerably.

Common yellow loam—of very indefinite composition—when added in the proportion of 25% did not have any material influence on the clinker.

Oyster shells, crushed to a powder, were next tried. They may be considered to consist practically of calcium carbonate, and as carbon dioxide is given off on heating, their effect should be the same as the addition of lime (CaO). The proportions of 25% and 5% were tried and the results were entirely bad. The coal clinkered badly, the clinker was very fluid and froze on and adhered to the bars and ran down between them, checking the draft. The clinker appeared also to attack the bars, chemically. It had to be removed by hammering when cold.

Lastly three iron compounds were used, pyrites (FeS_2), limonite ($2\,FeO, 3\,H_2O$) and the single sulphide (FeS). They were added in such proportions as to give in each case 23% of iron in three different tests for the purpose of seeing if the

Substance.	Melting temperature. With 25%.	With 50%.	With 75%.	Fluidity of melt
Al_2O_3	increased	increased	increased	very fluid
CaO	lowered considerably		increased	
Fe_2O_3	lowered slightly	lowered slightly	lowered slightly	viscous
FeS_2	lowered considerably	lowered considerably	lowered considerably	
Fe	lowered considerably	lowered somewhat	lowered slightly	very fluid
CaS_2	lowered	lowered considerably	lowered considerably	very fluid
$CaSo_4$	lowered	lowered considerably	lowered considerably	

amount of iron present was the important factor. In other tests the two sulphides were added in such proportions as to give the same amounts of sulphur present but different amounts of iron, for the purpose of finding whether the amount of sulphur present was the important factor. With 10% of iron present the pyrites (22%) did not have much effect on the clinker except that it made it somewhat denser. With 50% of pyrites (23% of iron) there was a hard and heavy clinker sticking close to the bars and choking the draft, and a strong tendency to cake developed. With 45% of limonite (23% of iron) the clinker was hard and more fusible than with the pyrites and the mass was hard to slice, but, nevertheless, the fire burned well and the general condition of the fire was much better than with the pyrites, due to the absence of the caking. With 37% of FeS (23% of iron) the clinker was heavy and difficult to handle, the conditions of the fire being very similar to that in the run with pyrites.

With 73% of FeS, which gives the same percentage of sulphur as in the test with 50% of FeS_2, the clinker was extremely troublesome, very fusible, and froze on the grates in the same manner as during the tests with oyster shells. The fire went very badly.

The tests with the iron compounds would seem to show that both the iron and the sulphur cause trouble. Some of the sulphur is driven off from FeS_2 on heating, leaving FeS, so that the tests with 50% of FeS_2 and with 37% of FeS are practically identical tests. Similarly, the test with 73% of FeS is to be compared with the test with 37% of FeS rather than with 50% of FeS_2. It would appear that the sulphur develops a tendency to cake.

This completes the investigations that have been carried out so far in an actual furnace. The net results are not of much practical value since the kaolin and crushed quartz, the use of which was beneficial, are not cheap enough to be regarded as commercially available. They show, as did the investigations on ash, that lime and iron oxides and sulphides cause trouble. Limestone has been used effectively to prevent adhesion of the clinker to the grates by spreading the crushed stone evenly over the thin, clean fire immediately after starting, but it will not prove effective after the clinkers have once formed. Experiments have not yet been carried out with fluxes of very low melting temperatures, as it is considered improbable that any such flux can prevent freezing on the grates. Some experiments along this line, however, are contemplated.

Conclusions.

The results of this inquiry may be summed up as follows: The elements the presence of which cause trouble from clinkering are principally calcium, iron and sulphur. The exact amounts of these which may be present without causing trouble is not at present known with sufficient accuracy to permit the use of a formula (such as Prost's) with any security. Prost's formula is correct in a general sense—that is, the fusion temperature increases as the alumina increases and falls with increase of the other elements—but its use cannot be relied upon for any particular ash. The only real cure for clinkering is low-temperature combustion. If the temperatures are high the trouble from clinkering can generally be reduced by the use of steam, or by the addition of kaolin or pure quartz, both of which, however, are too expensive to be commercially justifiable.

A LARGE THERMIT WELD.—The largest piece of process welding ever done on the Isthmus was turned out this week from Gorgona shops. It is one of the 18¾-in. shafts of the rock breaker "Vulcan," which is on subaqueous rock excavation in the Pacific entrance. This shaft forms a part of the ram by the weight of which the rock is crushed. It is made of compressed cast steel, is 56 ft. long and weighs 19 tons. Immediately after it was broken it was placed on a car and sent to the shops at Gorgona where a mold was made for a Thermit weld. The weld was made last week, 1,000 lbs. of Thermit and 200 lbs. of wire nails being used. After the shaft had cooled it was annealed and dressed, and is now ready for further service.—"Canal Record," Nov. 2, 1910.

Some Tests of Old Timber.

By C. P. BUCHANAN.*

The first teaching I received concerning timber was imparted by house carpenters and cabinet makers, men accustomed to using wood under little or no stress, and it ran about in this vein: *Wood is good for an indefinite life if properly seasoned and protected against dry or wet rot.*

The bridge carpenters with whom I was associated later were practically unanimous in their assertions that wood in bridges and trestles loses its "life," becomes dead and "brash" under traffic, so that it should be renewed in twelve or fourteen years regardless of the inspector's verdict. A talk with any master carpenter who is interested in his work will scarcely ever be very protracted if it doesn't bring forth some such remark as: "That bridge is ten years old and will have to be watched closely; and we must arrange to renew it within the next two years."

What influence such statements may have had in the matter does not now appear, but at any rate Mr. Max J. Becker, Chief Engineer of the Pittsburg, Cincinnati, Chicago & St. Louis Ry., instructed me early in 1884 to take some specimens from the chords of a Howe truss bridge that had been erected over the Big Darby near West Jefferson, O., in 1859, and to make compression tests to discover, if possible, whether the white pine of which it was built had so changed in character as to belie its appearance and be unsafe.

Upon securing eight pieces from different portions of the structure I concluded it would be more satisfactory to make some tests of new timber for comparison rather than to depend upon what had been done by others, doubtless under somewhat different conditions. So duplicate blocks were cut from some white pine that had been received and "sticked" in one of our bridge yards over a year previously and that was admitted by the master carpenter to be well seasoned and first-class stock.

The tests were made in the hydraulic machine of the Keystone Bridge Co. at its works in Pittsburg, Pa., in April, 1884. The specimens were all subjected to a uniformly increasing load until they failed by crushing. Loads were applied in the direction of the grain. Ten of the blocks, five old and five new, were 5 ins. long, and the others were 4½ ins. long. Transverse dimensions were approximately 5 by 6 ins., 3½ by 11 ins., 5 by 9½ ins., 5 by 10 ins., 6 by 11 ins., 7 by 10 ins., and 9 by 11 ins. The above table shows the results obtained.

The specimens from the bridge and two of those from stock timber were tested on April 4. It was then noted that the new timber seemed slightly damp, apparently having been wet in transit from the yard shop to the bridge works. The remaining six blocks were, therefore, placed in the warm dry racks of the bridge company's pattern shop and allowed to remain there for twelve days. My notes made at the time say the improvement in results due to this drying out was very marked.

It may occur to some one that the timber from the bridge was of better quality than from the stock yard. While this idea may be correct the difference, if any, would not account for such marked differences in strength. We still received a very good quality of pine 27 years ago, and the specimens were selected with care and from the best sticks in the yard.

*Assistant Engineer of Bridges, Pennsylvania Lines West; Union Station, Pittsburg, Pa.

At the present time the statement that timber is destroyed by worms and various boring insects, and by bacilli and fungi that attack the cellular tissue will hardly be questioned, as all the preservative processes in general use aim to inject a creosote or salt that will act as an antiseptic fatal to any of these agencies of destruction.

This is in line with the treatment of diseases that attack the human organism, as seems logical when it is noted that there are so many like characteristics, such as the varying susceptibility of different species and of particular members of the same family. As in the human family, there is no doubt that the absence of light and fresh air and the presence of dampness and heat facilitate the implantation and growth of the bacilli and fungi, so that proper ventilation and protection against storms are of great value in prolonging the life of timber.

I have been party to the replacing with metal of Howe truss spans, after they had been in service only ten years, in which decay was so advanced that the chord sticks would break in two if lifted at the ends, or by a line around the center, after being unpacked. Of course the rotten condition of the timber was easily detected upon inspection. When sounding, boring or cutting fail to show to the experienced observer any signs of change in the cellular structure of timber my experience leads me to believe that it is perfectly reliable and that its strength increases with age, the maximum value being close to the time when change in color of the borings or freshly cut fiber mark the first work of the destroyers.

The bridge from which the specimens reported were taken was replaced by a metal viaduct in the spring of 1896, and the timber was still in such excellent shape that the greater part of it was sent to the timber yard of the division and furnished stock for picture frames, blue printing frames, joists, rafters, sills and studding for various buildings along the line. Much of it is still doing duty without sign of failure. The last lot of it was hurried out of the yard a few years ago to furnish blocking and cribbing at a washout.

CRUSHING TESTS OF 25-YEAR-OLD AND NEW WHITE PINE.

Specimens from Bridge.			Specimens from Stock.		
Area, sq. ins.	Crushing load, lbs. per sq. in.	Remarks.	Area, sq. ins.	Crushing load, lbs. per sq. in.	Remarks.
29.25	5,780	Clear. Bolt hole mark ⅛-in. deep on narrow side.	30.00	4,510	Clear.
38.50	4,795	Clear. Heart. Slightly decayed.	28.50	3,210	Clear.
46.31	5,950	Sound. One sap corner.	47.50	4,570	Clear. Slight season cracks.
70.00	4,920	Clear. Heart. Well defined season crack.	70.00	3,900	Clear. Heart. Well defined season cracks.
			30.00	5,420	Clear. Slight season cracks.
29.25	5,330	Large black knot in longer side and end.	50.00	4,420	Clear. Heart. Slight season cracks.
50.00	5,100	Clear.			
66.00	5,440	Clear and slightly decayed.	63.89	4,070	Clear. Heart. Large season crack.
90.00	5,060	Clear. Heart. Well defined season crack.	96.52	3,970	Clear. Heart. Large season crack.
Average,	5,300.		Average,	4,260.	[Last 6, 4,390.]

DEPOSITING CONCRETE FOR STREET FOUNDATIONS by mechanical means has been adopted in a number of cases and by different types of apparatus. With a portable concrete mixer the concrete may be delivered upon a belt conveyor, a gravity chute (of very slight inclination), or a dump bucket travelling to and fro upon a horizontal boom. The boom, chute or conveyor is attached to the mixer and is pivoted so as to distribute concrete within a wide sweep. The conveyor and chute can deliver the concrete only at the ends, and the latter will require a man to keep the concrete moving with a spade or hoe. The bucket, however, can be dumped at any point between the mixer and the end of the boom. With appliances of this kind there is a considerable reduction of labor as compared with the distribution of concrete by wheelbarrows.

A 1,000-HP. CHAIN DRIVE has been recently installed at the mill of the G. & J. Tire Co. at Indianapolis, Ind. The chain is of the silent type running on V-toothed sprockets. The chain is of 3-in. pitch and is 24 ins. wide. The distance between centers is 103.24 ins. The sprockets have 61 and 83 teeth and run at 95 and 70 r. p. m., giving a chain speed of 1,448 ft. per min. The cost of this drive, which has run without repairs since April, 1910, is given by the makers, the Morse Chain Co., Ithaca, N. Y., as $3.67 per HP. An illustrated article on this drive and several others of from 175 to 500 HP. was published in the "American Machinist," Nov. 24, 1910.

The Development of the Municipal Water-Works of Spokane, Wash., and the Addition of an Electric Pumping Station.

By ALEXANDER J. LINDSAY.*

The question of water-supply for any municipality is an important problem. This is especially true if the city is rapidly increasing in population so that provision must be made for future growth. One of the best examples of this problem is seen in the city of Spokane, Wash., which has just completed the fifth addition to its pumping stations within 26 years.

FIG. 1. PUMPING STATIONS OF THE SPOKANE MUNICIPAL WATER WORKS.
(New Electric Station at the Right.)

The original settlement of Spokane was made on the Spokane River at the site of Spokane Falls. The original public water-supply was built in 1884 and consisted of a small pumping plant located in a flour mill. A few hundred feet of pipes were laid through the most populous part of the village. The pumps had a capacity of 350,000 gals. per day and were operated by hydraulic turbines which received water from the Spokane Falls. It is interesting to note that this original equipment is still in service doing duty as a portion of the newer and enlarged system. It serves to supply water from the low-pressure system to the highest points of the city, which have rapidly grown as a residence section. However, these will soon be displaced by motor-driven, two-stage centrifugal pumps, which are to be installed.

GROWTH OF THE MUNICIPAL WATER WORKS.—The growth of the city was up the river toward the east and the expansion was so rapid that in 1894 the original station had become so inadequate and the waters of the river so exposed to pollution that it became necessary to build a better and larger plant five miles above the center of the city. At this point the river had a natural fall of about 14 ft. At the upper end of this fall, a rock-filled dam was built which somewhat increased the head and also provided a certain amount of storage. The water from this pond was carried through an earthen ditch for about one-fourth of a mile to the gates immediately above the pumping station. From here the water passed through riveted steel flumes, 12 ft. in diameter, to a series of vertical turbines, which were connected to pumps on the floor above by means of shafting and gearing. The river furnished water for both power and domestic supply. As this plant was far above the city, the river water was absolutely free from contamination and was, therefore, used. The plant had a capacity of 10,000,000 gals. per 24 hours, which at that time was considered ample for Spokane for many years to come.

The adequacy of the water-supply was based upon the experience of eastern cities and their normal factor of growth. But Spokane grew much faster than the ordinary community and as early as 1898 it was necessary to add a new 4,500,000-gal. pump. This addition helped out temporarily, but in another four years it was necessary to add two 2,500,000-gal. pumps. These were driven by the same turbines which operated the original pumps, for it was found that the wheels had ample capacity to carry the added load.

As the city grew, the hills south of the business section rapidly became occupied and, as the elevation of these was too great to be served by the same system which furnished water to the rest of the city, it became necessary to build two auxiliary pumping stations, one at Fifth Ave. and Pine St. and the other on Bishop Court near Monroe St. These supplied 2,500,000 gals. a day from the low-pressure system to this hill section. These auxiliary pumps were driven by electric motors. An attempt was made to install high-pressure pumps in the main station on the river bank, but it was found that the old low-pressure force main was not capable of withstanding the high pressure necessary to reach the hill sections of the city. At the time this attempt was made, a new 30-in. riveted-steel, low-pressure, force main and a 20,000,000-gal. reservoir were built for the low-pressure service and four 2,500,000-gal. pumps were installed in the river station. The addition of these pumping units carried the total capacity of this system up to 29,500,000 gals. per day and the low-pressure system of the city was in splendid shape so far as quantity was concerned.

During all this time the valley of the Spokane River was being rapidly settled and the small town of Coeur d' Alene, situated where Lake Coeur d' Alene empties into the Spokane River, was rapidly becoming a city. This condition, existing above the point where the water-supply for Spokane was secured, naturally tended to jeopardize its purity, and city officials eventually found it necessary to condemn the source of water-supply. At first it seemed probable that a new and entirely different source would have to be sought and the existing pumping stations abandoned.

During the construction of the up-river pumping station it became necessary to dig pits for placing foundations and it was found that the water rose in these pits to a considerable height, suggesting that there was a source of water-supply either entirely separate from the river or that the pits were being supplied by infiltration. When it became necessary to seek a new supply, a very thorough investigation of the quantity and character of the underground water-supply was made. Test wells were sunk at various points from Coeur d' Alene Lake down the river to the water-works. Analyses of the water obtained from these wells showed it to be different from the water of the Spokane River. It was clear and pure and the only objectionable feature was its hardness due to contained mineral matter. It was thought that a sufficient supply could be obtained from this source but, to make certain before too great an expenditure was made, a large well 30 ft. in diameter was excavated back of the main pumping station. Two centrifugal pumps, with a capacity equal to that of all the pumping machinery in the city water-works, were connected to this well and operated for a long time. While the level of the water in the well was lowered to some extent during pumping, it immediately rose when the pump was shut down, and it was evident that the well had more than sufficient capacity to amply supply the city. This well was connected to the pumps in the river station and this supply was substituted for that from the river.

In the spring of 1908, the demand for water having again reached the capacity of the installed pumps, the two remaining wheels in the old station were loaded with two additional pumps of 2,500,000-gal. capacity each bringing the total capacity of the station to 34,500,000 gals. per 24 hours. While this helped out temporarily, it was apparent that additional facilities would have to be supplied and therefore plans were started to meet the requirements.

FIG. 2. INTERIOR OF NEW ELECTRIC PUMPING STATION, SPOKANE, WASH.

*Superintendent of the Water Department, Spokane, Wash.

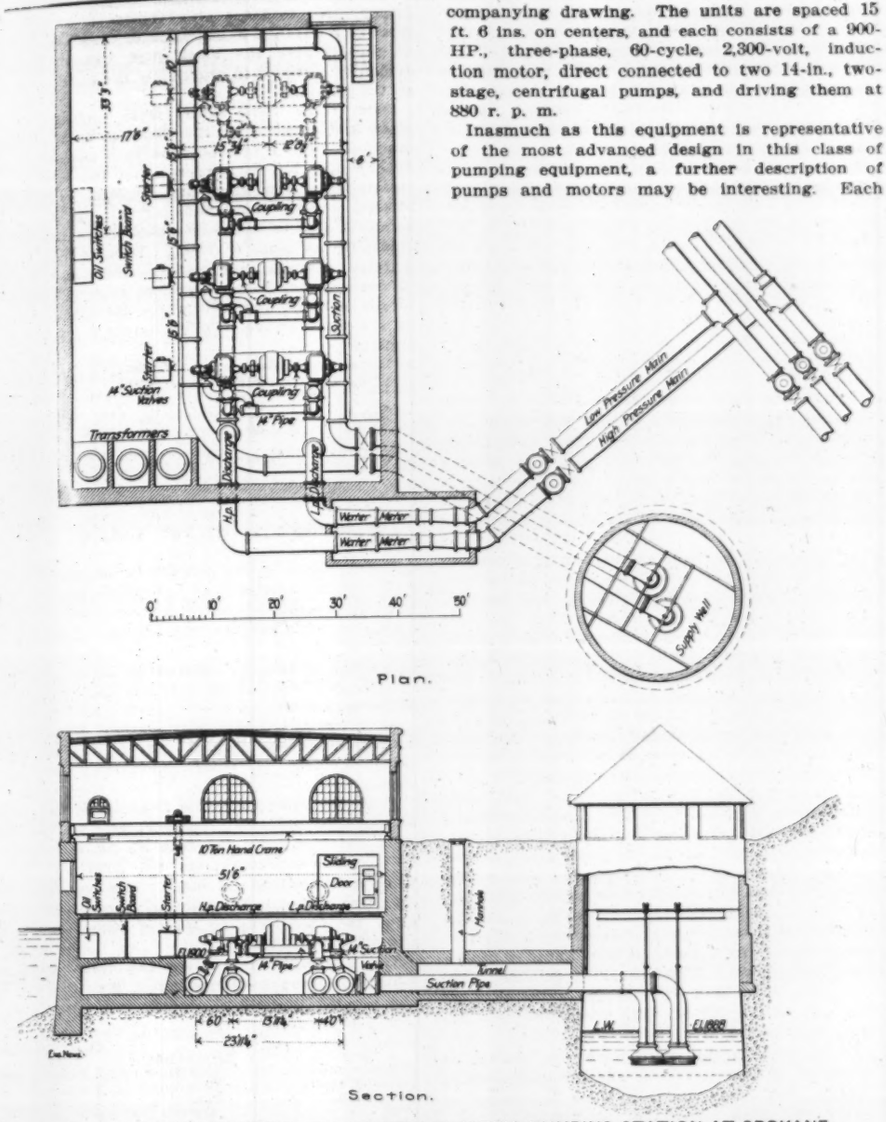


FIG. 3. PLAN AND SECTION OF THE NEW ELECTRIC PUMPING STATION AT SPOKANE.

It was decided that it would be best to dig a new well tapping the underground supply and to build an electrically-operated pumping station, as the power obtainable from the river was developed to its limit. Plans were drawn, bids were advertised for and finally a contract was let for furnishing three motor-driven centrifugal pumping units. The installation of these has just been completed, and is of particular interest as demonstrating the possibilities of this class of machinery for supplying water to large municipalities.

ELECTRIC PUMPING STATION.—The new pumping station, shown at the right in Fig. 1, is entirely independent of the older station, and is absolutely fireproof, being built with concrete foundations and steel and brick superstructure. It is supported on piling capped with a timber grillage, all of which is below low-water mark. The floor of the pumping station is itself 4 ft. below high-water mark. In order to insure water tightness the basement floor and the walls, to a height of 7 ft., were made waterproof by the use of asphalt felt and asphaltum. The interior walls are also made more impervious to the inseepage of water by being plastered with a coat of neat cement which also improves their appearance. The interior dimensions of the station are shown on Fig. 3.

The three pumping units now installed are placed along one side of the station with their shafts parallel to each other and at right angles to the side of the station, as shown in the accompanying drawing. The units are spaced 15 ft. 6 ins. on centers, and each consists of a 900-HP., three-phase, 60-cycle, 2,300-volt, induction motor, direct connected to two 14-in., two-stage, centrifugal pumps, and driving them at 880 r. p. m.

Inasmuch as this equipment is representative of the most advanced design in this class of pumping equipment, a further description of pumps and motors may be interesting. Each centrifugal pump is a two-stage, single-end suction, horizontal-shaft type. It is supported by brackets, cast integral with the casing, which rest upon and are bolted to a base plate. The shaft is made of open-hearth steel and a bronze sleeve is used to protect that portion of the shaft exposed to the action of the water. The impellers, are of the enclosed type, made entirely of bronze, and are fastened to the shaft by means of a feather key and nut. A stationary guide passage is placed between the two impellers, its function being to take the water from the tips of the vanes of one impeller and deliver it through suitably shaped passages to the inlet side of the succeeding impeller. The last impeller discharges in a radial direction through guide vanes into the casing. A balancing disk, connected with both the suction and discharge sides of the pump, maintains a practically perfect running balance. The bearings are of the ring-oiled type lined with composition metal and the oil is supplied from a large reservoir. Stuffing boxes on both the discharge and suction sides of the pump are provided with bronze water-sealing rings to prevent ingress of air.

The motors are a standard design. The rotors are coil-wound and connected to the speed-control starting circuit through collector rings. The starting devices furnished with each motor include a bank of cast-iron resistance grids mounted in an expanded metal case. For starting this resistance is connected into the rotor circuit by the collector rings. The resistance of the grids is such that a period of two minutes may be consumed in bringing a motor up to full speed with a temperature rise in the resistance not exceeding 175° C. The starters cut out this resistance in steps to secure proper acceleration of the motor. The collector rings are short circuited by a manually operated device when the motor is up to full speed.

Heavily insulated, lead-covered cables, placed in the concrete floor, connect the motors to the switchboard. Similar cables, carried in conduits in the wall of the building, connect the transformers to the switchboard. As shown in Figs. 2 and 3, the switchboard is located at one side of the station with the high-tension oil switches in concrete cabinets back of it. The switchboard is made up of four panels of blue Vermont marble mounted on an iron frame work which leaves a space of 25 ins. between the bottom of the board and the floor. On the swithboard are mounted an ammeter, an integrating wattmeter, a voltmeter and various other necessary instruments. Three 1,000-KVA oil-insulated water-cooled, single-phase transformers, in one corner of the room, change the 13,200-volt line current to 2,300 volts for station service. Taps are provided on both windings which give approximately 3%, 6% and 9% lower voltages. The transformers are connected with a grounded neutral, and if one should fail it can be disconnected by means of switches, so that the station can be operated at about half capacity on the two remaining transformers.

Fig. 4 shows the supply well during construction. It is interesting to note that the bottom of this well can be plainly seen, although filled with water to a depth of 15 ft. From this well, two 30-in. suction pipes, of riveted steel with flanged joints, and arranged with foot valves, lead to the station and form a loop around the pumps. If it should be necessary at any time to repair one of these lines the total water supply of the station can be taken from the other. The suction pipes are carried from the well to the station through a concrete tunnel which is sufficiently large to allow for inspection and repair of the piping.

The discharge pipes are all of cast iron and

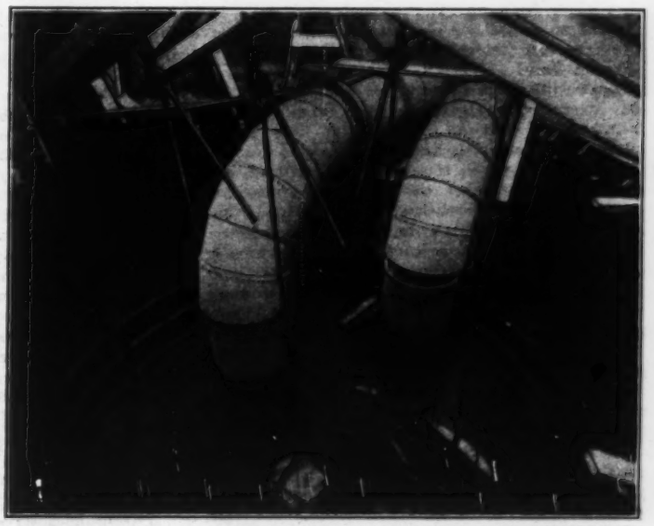


FIG. 4. VIEW OF SUPPLY WELL FOR THE ELECTRIC PUMPING STATION, SPOKANE MUNICIPAL WATER WORKS.

have flanged joints throughout. From Fig. 3, it will be seen that ordinarily both pumps of a set will discharge to the low-pressure main. With this arrangement, each unit has a capacity of 12,000,000 gals. per 24 hours, against a head of 260 ft. However, in case of fire or other necessity for a higher pressure, the discharge from one pump of the unit can be connected to the suction of the other pump in which case the discharge of the second pump is led to the high-pressure main. Under these circumstances the units have a capacity of 7,500,000 gals. per 24 hours, against a head of 430 ft. Venturi meters are placed on the discharge of both the high pressure and low pressure lines.

The complete pumping units were made by the Allis-Chalmers Co., of Milwaukee, Wis. Although the station was designed for four units only three have as yet been installed and the fourth will be placed in position when needed. The units run with practically no vibration and are easily regulated to maintain any desired pressure. After operating the station for a short time in a preliminary way to properly make adjustments, it was put in regular service and has been delivering water to the city for about two months. Every one who has been connected with the development of the plant has been gratified with the success which has so far attended the operation of this electrical equipment.

Corrosion of Hot-Water Piping in Bath-Houses.

By IRA H. WOOLSON,* M. Am. Soc. M. E.

The following investigation was made while the writer was in charge of the Testing Laboratory at Columbia University; this paper represents the progress of the work up to May, 1910, when he severed his connection with that institution. The original plan was to collect further evidence upon the subject before publication, but, as that is now impossible, it is thought best to make public the results thus far obtained, in the hope that they may be of some service to those interested in the subject.

My attention was first called to this subject in 1908, when I was requested by the Bureau of Buildings of New York City to investigate the cause of very serious corrosion in the hot-water pipe system in the East 11th St. public bath. The whole hot-water system was found to be very badly corroded and leaking, and it was decided to install an entirely new system of piping. The bath had been in use about four years.

Examination of the ruined pipe showed that it was pitted on the bottom and sides with the characteristic holes which result from local electrolysis. The corrosion was all from the inside, there being no evidence of outside corrosion, which proved it was not due to stray current from any electric circuit. This was further evidenced by the fact that the corrosion was confined to the hot-water system. The pipe (galvanized) appeared to be of good quality; no special effort was made to determine whether it was steel or wrought-iron.

Last winter the subject was again brought to my attention by reports of similar trouble in other bath-houses, and an investigation was undertaken (1) to ascertain, as far as possible the conditions under which this corrosion occurred, and (2) to learn whether the pipe was steel or wrought-iron, and whether the material had anything to do with the tendency to corrode.

It is not my purpose to discuss the causes of this very serious deterioration of hot-water pipe. That is a subject for specialists who are studying the problem of metal corrosion. I will simply give a statement of conditions as I found them.

Since the trouble was confined to the hot-water system of pipes, it was apparent that the corrosion was stimulated in some way by heating the water. Assuming that electrolytic action influenced by heat was involved, an experiment was made to ascertain what temperature would produce a maximum effect. A small galvanic cell was made by immersing 2-in. strips of sheet steel and zinc in a beaker of ordinary Croton water, the cell being connected to a millivolt galvanometer. It was found that heating the water increased the current obtained. The gain was gradual up to about 180° to 190° F., when the accumulation of air bubbles upon the plates seemed to arrest the electrolytic action.* It was surprising to note that a cell of this character would produce 0.3 volt.

I later ascertained that this trouble was recognized by some engineers having charge of hot-water heating systems, and their experience corroborated my experiment, namely, that the corrosion was greatest when the temperature of the water was somwhat below the boiling point, also that the action is aggravated where large quantities of hot water flow through the system. The rapid circulation of a fresh supply of water past the infected spots probably brings to them plenty of oxygen, which serves to hasten the corrosive action.

About this time it was learned that the same difficulty had developed in the hot-water distributing system in one of the handsomest apartment hotels in the city, and was causing the management much worry and inconvenience. The trouble had just begun, but as it is certain to be progressive, the situation is a menacing one.

It is evident that this problem in pipe deterioration is one which will warrant the careful thought of the best experts. So far as I know, a satisfactory remedy for this trouble has not been found. It has been suggested that the difficulty can be controlled in a large measure by reducing the water temperature to about 110°, and I understand this plan has been tried with some success. I am told that the Consulting Engineers now having the bath-houses in charge are planning to arrange the various systems to deliver water at a temperature not higher than 110°.

In this investigation I visited all the public bath-houses of New York City, carefully noting conditions, and collecting all the samples of corroded pipe I could secure. In some places it was difficult to get satisfactory samples, because the old piping was sold for junk as rapidly as it accumulated. I examined eleven baths in all, but three of them were new and samples of corrosion were secured from only eight. These were located as follows: 538 East 11th St.; 243 East 109th St.; East 76th St.; 324 Rivington St.; 133 Allen St.; East 23d St.; 232 West 60th St.; 347 West 41st St.

In all these baths there were very numerous evidences of this corrosion, and the engineers in charge were unanimous in their testimony of worry and work caused by this trouble.

Croton water is used in all the baths and this is heated in various standard types of heaters. As a rule the water is heated to about 160° to 200° F., and the water is circulating for bathing purposes from 6 a. m. to 10 p. m. each day. Some of these houses give 30,000 to 40,000 baths per month in the warm weather. I was unable to ascertain the amount of water passing through these hot-water pipes, since they are not separately metered. In some buildings even the meter on the main intake pipe was not in service.

In all cases where the pipe had been in use four years or over trouble had begun, and in a few places pipe had been perforated in less than three years. In the 11th St. bath some of the new piping put in two years ago had pitted through again and been replaced a second time.

The corrosion is worst on the bottom and sides of the pipe, and pipe in horizontal position suffers more than that which is vertical.

I collected 89 samples of pipe from these various bath-houses, all of which had pitted through and had been removed as worthless. The samples were of varying sizes from ¾-in. to 4-in. diameter, but the majority were 1¼-in. and 2-in. diameter. As a rule the pipe was galvanized, but a considerable number of black-pipe samples were also obtained. No evidence was obtainable as to the relative resistance to corrosion of these two kinds of pipe. Where the black pipe was in use it evidently corroded in practically the same manner as the galvanized.

Short rings were sawed from each of these pipes and crushed on the diameter in a testing machine. The fractures were then examined independently by two experts and the specimens classified as iron, steel, and doubtful. Chemical analyses were then made of all the doubtful samples, also of a few samples which had been classified as iron or steel. These analyses of doubtful samples confirmed the visual separation in nearly every case, and were in perfect accord on all samples analyzed where the classification by eye was positive. Following are a few typical analyses:

Manganese.	Carbon.	Oxide.	Classified as
.48%	.09%	.20%	
.32	.08	.26	
.42	.08	.21	Steel.
.38	.08	.30	
.50	.08	.38	
Trace.	Trace.	2.85	
"	"	2.40	
"	"	2.20	Iron.
"	"	2.50	
"	"	1.75	

The difference in the two kinds of metal is clearly shown.

To eliminate every possibility of samples of steel being classified as wrought-iron, all the samples determined as wrought-iron were etched, and then all samples that were in any way doubtful among either the steel or iron were examined under the microscope and classified by Dr. William Campbell of the Department of Metallurgy.

As a result of this very careful scrutiny, it was unanimously decided that of the 89 samples collected, 17 were undoubtedly wrought-iron.

These iron samples came from six of the eight bath-houses previously enumerated. No samples were obtained from the 60th St. house, and the 16 samples collected from the Allen St. house were all identified as steel. The wrought-iron pipe was mixed indiscriminately among the steel pipe, and there was no way of telling one from the other until tested.

The following table gives the bath-houses at which the wrought-iron samples were found, and the number of both steel and iron samples collected from each:

Material applied on contract.	Bath-house.	Classification of samples.
Probably steel	11th St.	2 Iron— 6 Steel
Probably steel	76th "	2 " — 5 "
Not certain	23rd "	2 " — 4 "
Steel	41st "	5 " — 7 "
Steel	Rivington "	2 " —23 "
Steel	109th "	4 " —11 "
		17 56

Total from houses which furnished mixed samples, 73.
Steel Allen St. 16 Steel
Total of all samples 89

It will be seen that of the 73 mixed samples, 23% were wrought-iron.

An investigation of the contract specifications for these houses showed that all except two called for "galvanized wrought-iron pipe." However, in the plumbing trade this term is commonly taken to cover both wrought-iron and steel pipe, of the welded form, and under such specifications steel pipe is generally furnished.

The probable explanation of the presence of the wrought-iron samples among the steel samples is that the pipes were accidentally mixed either by the manufacturer or the jobber. A few years ago the leading manufacturers were making both kinds of pipe, and under such conditions it is not unlikely that the two varieties may have been confused in shipment.

In my judgment, from the evidence collected, there was absolutely no difference in the corrosion of the two classes of pipe. They appeared to be equally susceptible to the attack.

THE NORTH SHORE DRAINAGE CHANNEL, an auxiliary of the Chicago Drainage Canal, was opened Nov. 29. A cut was made in the dam separating the channel from Lake Michigan, the work being done in the presence of Mr. R. R. McCormick, President of the Sanitary District, and Mr. Geo. Y. Wisner, M. Am. Soc. C. E., Chief Engineer. For the Calumet or Sag channel, the purchase of right-of-way has been in progress for some time, and it is expected that construction work will be commenced next spring.

*Consulting Engineer to National Board of Fire Underwriters, 135 William St., New York City.

*The following passage in a recent issue of "Mitteilungen, etc.," of the Royal Testing Institution at Gross Lichterfelde West, Berlin, Germany, corroborates these observations:

> Rusting tests at higher temperatures showed in all cases considerably increased corrosion. The increase of rapidity of attack progresses up to a definite temperature lying between 60° and 80° C., beyond which the rate of corrosion decreases again.

This statement refers to experiments made by Heyn and Bauer.—Ed.

ENGINEERING NEWS

A Journal of Civil, Mechanical, Mining and Electrical Engineering

Published every Thursday by

THE ENGINEERING NEWS PUBLISHING CO.

220 BROADWAY, NEW YORK

BRANCH OFFICES

CHICAGO: 1636 Monadnock Block
BOSTON: 43 Tremont Street
WASHINGTON, D. C.: Home Life Building
SAN FRANCISCO: Monadnock Building
RUDOLPH MOSSE, BERLIN AND HAMBURG, GERMANY
Z. P. MARUYA & CO., Ltd., TOKYO, JAPAN

GEORGE H. FROST, President
CHARLES WHITING BAKER, Vice-President
FRANCIS W. FROST, Secretary and Treasurer

ARTHUR E. KORNFELD, Manager

CHARLES WHITING BAKER, M. N. BAKER, H. M. R. TRATMAN, F. E. SCHMITT, } Editors

SUBSCRIPTIONS

United States and Possessions, Mexico and Cuba, One Year, $5.00.
Canada, One Year; $7.00; Thin Paper Edition, $6.00.
Foreign Countries, Regular (Thick Paper) Edition, One Year, $9.00. (£1-18-0.), 45 Francs or 37 Marks.
Foreign Countries, Thin Paper Edition (Construction News Supplement Omitted), $7.00. 29 Shillings, 35 Francs or 29 Marks. Remit directly to our office.
Pay no money to canvassers for subscriptions.
Remit by Post-Office or Express Money Order, Draft on New York or London, or by Registered Letter.
Notice of change of address should reach us one week in advance of removal. The old as well as the new address should be sent.
Subscriptions cannot be dated to commence with past issues. All subscriptions commence with current issue and back numbers can be supplied only by special order.
Receipts for Subscriptions will not be sent unless requested, the changing of the expiration number being considered sufficient. The number on the address label indicates when subscription expires, the last figure indicating the year and the one or two preceding figures the week of that year. Thus 520 means the 52d week or December 29, 1910.

ADVERTISING

"Contract": Rates furnished on application.
"For Sale": $1.50 per inch.
"Proposal": $2.40 per inch.
"Want": See "Want" Pages.

Copy for regular, or "Contract," Advertisements should be received at least ten days before publication; "For Sale" and "Situations Wanted" Advertisements by Monday, and "Proposal" and "Situations Open" Advertisements by 9 A. M. Wednesday.

Entered at the New York Post-Office as Second-Class Matter.

Fifty-seven years of continuous service! That is the remarkable and honorable record of Mr. D. J. Whittemore, who has just resigned the Chief Engineership of the Chicago, Milwaukee & St. Paul Ry. Mr. Whittemore has been Chief Engineer of this company for 47 years and for ten years previous to assuming that position he was in the service of the same company or its predecessors. The circular issued from the President's office on Dec. 1, announcing Mr. Whittemore's resignation says:

> In recognition of the high character and unusual length of his service, the honorary position of Consulting Engineer has been created, and he has been appointed thereto.

It is needless for us to say that such long service in one position, or any period approaching it, is extremely rare in the engineering profession. Most engineers are rolling stones, not because they prefer to be or because they are opposed on principle to gathering moss and other desirable things; but because they are compelled to roll.

It is all the more pleasant, therefore, to record Mr. Whittemore's long service. The corporation or the municipality which can secure and retain an efficient engineer in its service throughout a long period of years, is likely to secure a far better quality of engineering work than can be secured under the too-common conditions of frequent and sweeping changes in the official personnel.

Which is the stronger; a piece of sound old timber or a piece of new? We think it probable that the majority of engineers would say that the new timber was the stronger. In either case, however, the opinions would be mere guesswork, for there had been hitherto, so far as we recall no authentic information on this point. This lack is now supplied in a paper by Mr. C. P. Buchanan, published elsewhere in this issue, in which he shows as a result of careful tests, that sound timber a quarter of a century old is materially stronger than new stock.

Mr. Buchanan's tests were made on white pine, but there is no reason to suppose that oak, hard pine or any other wood commonly used in building would behave differently. It is fair to conclude that all wood maintains its strength, except as decay weakens it or fire and mechanical abrasion destroy it.

It may be said that engineers are already using wood for permanent service where it is kept under water. Its permanent reliability under such conditions is literally a foundation fact in engineering. For use in superstructures, however, engineers are prone to look upon wood as a perishable and temporary material.

Admittedly wood above water is subject to destruction by fire and decay, but if these two enemies are kept away it is difficult to set a limit to the useful life of wood. Mr. Buchanan's tests were of wood only 25 years old, but there are plenty of wooden truss bridges all through the East whose structures have been protected from the weather and which have been carrying traffic for 50 to 100 years. The bridge over the Hudson at Waterford, N. Y., which burned down last year, will be recalled; that structure was in service about 105 years. Many European travelers will recall noted wooden bridges and other wooden structures abroad of much greater age. In fact, were it not for the increasing cost and scarcity of good timber, there is reason to believe that many county highway bridges of moderate span and light loads would be actually more permanent structures, having longer life and involving smaller cost for maintenance during their life, if built of wood than if built of steel.

Although wood is the oldest historically of our constructive materials, yet the question of change of strength with age has never before been studied. This state of affairs is suggestive of numerous other gaps in our knowledge of materials. With the great activity in testing during recent years, many of the gaps are being filled. The question of deterioration of structural iron in bridges, for example, was a matter for speculation until within the last half-dozen years, when a number of systematic tests on old Prussian bridge iron demonstrated the absence of deterioration. However there are still plenty of unsolved problems in our knowledge of the strength of materials to furnish ample opportunity for investigators, and this field of knowledge is so important to the engineer that progress in exploring its unknown corners is specially welcome.

A steam boiler efficiency record of 82.36% is high enough to deserve attention. A boiler test in which this figure for efficiency was reported was recently offered us for publication. The test was made upon boilers purchased by the Government under a contract which provided a handsome premium for high efficiency. The test was made by an engineer acting for the Government and upon its results, we understand, some $18,000 was earned as a premium by the builders of the boilers tested.

All this was certainly important and interesting—if true. Before publishing the report of the test, however, we examined the detailed figures to see if we could find any indication how this excellent efficiency was obtained. We were surprised, indeed, to find that the figures reported showed serious inconsistencies. The factor of evaporation given did not check with the final results reported. It was impossible to determine certainly what error had given rise to the discrepancy; but the most likely explanation seemed to be that the engineer computing the test had credited the amount of superheat twice. The boiler was fitted with an attached superheater, giving about 100° of superheat.

We took up the matter with the makers of the boiler, who had furnished us the report of the test; but they were unable to explain the discrepancy. We then referred the matter to the Government engineers who had conducted the test and are still waiting for their answer.

We should not have referred to this matter in these columns at all save that one of our contemporaries, which devotes itself solely to power plant engineering and might be supposed, therefore, to be an authority in this field, printed in its last issue the report of the test in full exactly as it was originally submitted to us and place at the head of the article in large display type, "A BOILER EFFICIENCY OF 82.36 PER CENT."

Having thus aroused the interest of its readers interested in steam boiler design and operation, we trust our contemporary will not stop; but will proceed in its next issue to satisfy their (and our) reasonable curiosity as to the advances in the art of boiler design by which this high efficiency was obtained.

We venture the surmise, however, that this high record efficiency was not obtained by *design* at all. We think it probable that the engineers who made the test and the builders of the boiler were perfectly honest, and that it is just a case of somebody blundering in his arithmetic—a blunder, however, which cannot too soon be corrected.

In discussing the results of the decision of Judge Sanborne in the case of the Peoria Water Works Co. against the Central Ry. Co., brought to restrain the latter from operating its electric railway system unless the electrolysis of the former's pipes was absolutely prevented (Eng. News, Nov. 17, p. 539), we noted that this opinion seemed to indicate that the courts would not demand an absolute freedom from operating injury to the system of one public-service concern by the operation of a second public-utility, if such freedom unreasonably increased the expense or hazard of operating the service complained of.

Another recent decision confirms this evident tendency of judicial opinions. Some two years ago, the Postal Telegraph-Cable Co., the Western Union Telegraph Co. and the Lake Shore & Michigan Southern R. R. Co. brought suit against the Chicago, Lake Shore & South Bend Ry. Co., operating a 6,600-volt single-phase railway line between Chicago and South Bend, Ind., to restrain this last named concern from operating its single-phase system on account of excessive inductive interferences with adjacent telegraph and telephone service. The court of first hearing (Superior Court of Laporte County) ruled against the complainants and the Appellate Court has now confirmed that decision. The opinion of the latter court is interesting in many respects. In brief, the finding is that there was no showing of negligence, malice or unskillfulness on the part of the defendant and that the trouble experienced by the complainants was *damnum absque injuria*—"damage without injury." The decision continues:

> In the absence of any physical injury to plaintiff's property or the actual taking of any of it the mere interference by induction with a use which the plaintiff desired to make of such property caused by the use to which defendant devotes its own property in the operation of its cars by electricity does not constitute a wrong which can be enjoined, even though defendant threatens to extend such use to the degree of entirely destroying the value of plaintiff's telegraph lines.
>
> As between the two parties, both using electricity, but for different purposes, under public franchises granted by the Legislature, and both conducting business in which the public is concerned, priority of use does not give an exclusive right.

This decision does not seem to place on the complainants the requirement of active co-operation in lessening the total burden of interference to that irrepressible minimum which may be fixed by the state of the art in question, as did the decision in the Peoria electrolysis case. Nevertheless, the two cases seem to have a certain similarity because there are certain devices and measures which may be adopted by the telegraph and telephone companies to counteract the evils complained of. We remember that such remedies were worked out in connection with the installation of alternating-current traction on the New York, New Haven & Hartford R. R. near New York City and on the Erie R. R. at Rochester, N. Y. (Eng. News, Oct. 17, 1907, p. 401), and seem to have been fairly satisfactory—at least these roads are still operating and so are the nearby telephone and telegraph lines.

The Steam Jet as a Means of Preventing Clinker in Boiler Furnaces.

It is probable that the clinkering of coal in steam boiler furnaces has caused more trouble and profanity in the operation of steam power plants than any other single item in the whole outfit. Yet the young engineer—or old engineer, either—who gets into trouble with clinkers and undertakes a search through engineering literature to see what others have done to get out of trouble, will find a large and eloquent void.

We are very pleased, therefore, to present in this issue a paper on the Clinkering of Coal, by Prof. L. S. Marks, of Harvard University. The paper is the outgrowth of extended investigations and experiments made by Prof. Marks for one of the largest coal users in the East. While the results of Prof. Marks' investigation are in a certain sense negative,—that is to say he offers no panacea for troubles with clinker—his paper presents the whole situation regarding the production of clinker very clearly and cannot fail to be of interest and usefulness to any engineer having trouble with clinkering coal.

The principal remedy for bad cases of clinkering, Prof. Marks states, is the introduction of a steam jet in the ash pit. This cools the bed of coal on the grates and reduces the liability to melting of the ash and consequent formation of clinker. This remedy, says Prof. Marks, is well known. We doubt, however, whether it is so generally known and understood that more extended discussion of it is not worth while.

The use of steam jets around and under, and over a steam boiler furnace is about as old as the steam boiler itself. Legions of patents have been taken out on about every possible combination of steam jets with a boiler furnace that can be imagined, yet new ones crop up every little while. The steam jet may be arranged to give a very good forced draft, although as often applied it is rather extravagant of fuel. This draft may be applied either in the ash-pit or above the grate. In the latter case it may be of service to secure complete mixing of the combustible gases with the air, and consequent complete combustion and freedom from smoke. The steam may be superheated between its exit from the boiler and its issuance from the jet, and the entering air forced in by the steam jet may also be heated. With these other applications of the steam jet as a blower, however, we will not now concern ourselves; but the use of the steam jet for preventing clinker seems to deserve a wider knowledge and more general application.

One illustration of the efficacy of the steam jet for this purpose, when properly applied, is the Parson system, which has been quite extensively applied on boilers using various low-grade fuels. With these low-grade fuels some sort of forced draft is generally essential to force sufficient air through the narrow interstices of the fuel-bed. It is also necessary to keep down the temperature of the fuel-bed in order to prevent trouble with clinker, since many of the low-grade fuels contain a high percentage of ash.

While appliances of the type referred to have been extensively used and applied in many different ways, they have not had, it seems to us, the reputation and standing that they really deserve among engineers. This is partially due, we presume, to the way in which these steam jet inventions have often been exploited. They have been promoted and advertised as revolutionary improvements in boiler or furnace practice, and claims have been made for them which could not be substantiated. They have frequently been installed, moreover, on the idea that one remedy would fit all diseases. The same appliances have been attached to boilers operating under totally different conditions; and good results obtained in one place have been counteracted by failures in another.

Steam jet devices, furthermore, have generally had the reputation of being "steam eaters." Part of this is due probably to the fact that the devices have often been put in and allowed to run for months or years without any attention other than that given by the fireman. Now a steam jet issuing from a small orifice is certain to do one of two things; either it will become choked up with scale and inoperative, or else the orifice will be rapidly cut out and enlarged by the current of steam. When this happens the fireman will endeavor to avoid the excessive loss of steam and over-draft by throttling the jet with the valve on the pipe. The result of this, however, is that the steam jet operates at much lower pressure than is necessary for good efficiency so that a large amount of steam is required to do the work.

The effect of steam upon the fire is one of the points on which the exploiters of steam jet apparatus have generally spread themselves. It has been frequently claimed, for instance, that the steam jet produced water gas in the furnace, which would burn so efficiently that the fortunate owner of the plant could get more out of the coal in the way of heat units than it reasonably contained. This sort of sweeping claim, however, is not so commonly heard now as formerly.

It is probable that under proper conditions a jet of steam issuing in the ash-pit of a boiler furnace and drawn through the fuel-bed may actually be decomposed in the process, the reaction being similar to that which takes place in the ordinary water gas producer. If and when this takes place, it should produce a cooling effect upon the fuel-bed much greater than that which would be accounted for merely by the heating of the steam from its original temperature up to the temperature of the furnace. By the decomposition of water vapor into hydrogen and oxygen, a large amount of heat is absorbed. Part of this heat is, of course, furnished by the combustion of carbon to form carbonic oxide gas. The resulting hydrogen and carbonic oxide will then burn with a long blue flame combining with the oxygen from air admitted above the grates.

If this reaction as above described takes place, there need be no loss of heat due to the use of steam in the steam jet blower, the heat given out by the combustion of the hydrogen above the fire being equal to that absorbed in separating the hydrogen from its oxygen in the lower zone. The advantage gained, therefore, would be the transfer of the hot zone from the fuel-bed or its immediate vicinity to the combustion chamber. If in this way the fuel-bed is cooled enough to prevent the fusing of the ash and the formation of clinker, the actual advantage in economy and capacity may be of exceedingly great importance.

Of course, there will admittedly be a certain amount of heat loss, even with this complete combustion; that is, for every pound of steam delivered in the furnace and finally sent up the chimney with the flue gases, an amount of heat will be absorbed measured by the difference in the temperature of the feed water and the temperature of the chimney gases. With good boiler practice, however, the latter temperature should be reduced to such point that the loss of heat would be comparatively moderate; and with efficient steam jets, well maintained, it should be possible to deliver an amount of steam into the ash-pit sufficient to prevent clinker without serious reduction in boiler economy.

There is another question in connection with the use of the steam jet that is worthy of attention. It is the question whether, apart from any mixing effect that may be produced by steam jets over the fire, complete combustion is not facilitated by the presence of either water vapor or hydrogen in the combustion chamber. If the presence of a moderate amount of water vapor reduces the percentage of carbonic oxide in the flue gases, or the air excess necessary to secure complete combustion, the loss due to the passage of the water vapor through the furnace might be more than offset.

While we cannot quote any scientific experiments in proof of this point, there is considerable reason to believe that the presence of water vapor in a furnace does in some way tend to promote combustion. We have described above the reaction that takes place when water gas is produced with the emission of carbonic oxide and hydrogen. The high temperature produced by the combustion of hydrogen is well known. It is quite within possibilities that the high temperature produced in a mixture of carbonic oxide and hydrogen gas may aid to the complete combustion of the carbonic oxide.

It seems unfortunate that more complete scientific tests have not been made upon the action of steam in connection with the combustion of coal, particularly in connection with the deep fuel-beds and heavy forced draft which are common in modern boiler practice. If it is possible to use steam jet apparatus in a systematic way to keep down the temperature of the fuel-bed under such conditions and transfer the zone of highest heat to a point some distance beyond, this matter is one of much importance to all interested in steam power engineering.

LETTERS TO THE EDITOR.

Economic Comparison of Railway Tie Material.

Sir: Mr. E. A. Sterling's criticism (Engineering News, Nov. 17, 1910, p. 540) of the writer's article, entitled "An Economic Comparison of Railway Ties of Different Materials," which appeared in Engineering News, Sept. 22, 1910, p. 302, is in some respects just; yet the article fully explains its purpose in the first paragraph, which states that "It is not the purpose of this article to arrive at any final results which would apply in any locality or time but merely to show methods of comparison and results obtained by their use."

We do not know by whom the formulas were first devised, but we claim no credit for the ideas which they contain, as our letter to the Editor of Engineering News clearly states:

> The substance of formulas 1, 2 and 3 was used by Prof. S. S. Roberts in a class in the economic theory of railway location and it was in that way I got the ideas. Of course I worked the formula out in a little more detail and added the other formulas, which are constructed in identically the same manner as 1, 2 and 3. I do not know if the formulas in this form have even been published although I should not infer that the ideas they contain are by any means new. In presenting them I do not wish to claim honor for presenting any thing new, but merely giving in convenient form truths which are already known.

The footnote to the article explains this also.

As to the data contained in Tables 1 and 2, we realize that in some respects it is not satisfactory and could not be applied under any given set of conditions unless those conditions are average conditions, but for the purpose of the article and where ties are used under average conditions the data is valuable.

In our compilation of data we found great variation in regard to both life and cost of ties, for example in parts of Texas and Oklahoma the life of a white oak tie untreated is from four to five years, while in parts of Michigan and Canada they have given 15 or 16 years' service in main track after which they were put in side track and gave four to five years' service.

In regard to catalpa we are perfectly aware that it is a timber not used on a commercial scale and will not stand heavy traffic unless protected against mechanical wear, yet on the authority of one who has used the timber it has given service for more than twenty years.

Yours truly, Neil N. Campbell.

Lake Forest, Ill., Nov. 29, 1910.

Good Street Paving as a Promoter of Public Morals.

Sir: There is one very important reason why streets should be improved, which the writer has rarely seen presented, and that is the moral effect upon the residents. Of course the improvement is more readily perceptible when the moral tone is low; but it is decidedly evident in all cases. One would not expect much change in a street peopled with angels but I feel sure even they would burnish up their crowns a little brighter.

The writer observed a case in point a number of years ago. A street in a small city was occupied by railroad trainmen and their families, people of comfortable circumstances and steady incomes as compared with the average inhabitants of the town. Most of the houses had ample gardens and lawns; but almost without exception they were ill-kept, and more than one of the owners spent much of his income in gambling and riotous living to the neglect of his family.

The city authorities decided to pave the street although the improvement was bitterly opposed by the residents, and the writer as engineer was almost mobbed while making the surveys. The street was finally paved, however, and presented a neat and smooth appearance. Within a year or two every house on the street had been painted and put in good repair and the street became, in fact, quite a model in appearance. What is more, the former careless, gambling residents spent most of their spare time in the care of their lawns and

...s, gave up gambling, etc., and saved their money, ...to the advantage of their families.

... writer was personally acquainted with the sub... of this little story and knows that the results were ...ly due to the paving of the street.

F. W. D.

...w York, Dec. 1, 1910.

Transition Curves by Slide-Rule.

...: In connection with the articles on the Transition ...ve in your issues of Oct. 13 and Nov. 17, I think ... the case with which the computation of the deflec... may be made by the ordinary 10-in. slide-rule ...ld be mentioned.

...or finding the length of the curve from the ele... of the outer rail and the rate by which the eleva... is gained, the number of chords to be used may be ... from a desired chord length. From the number ...ords and the degree of the circular curve, the ... in curvature per chord may be found. The de... in minutes for the point at the end of the first ... may be found from the formula given in Kellogg's ...tion Curve: $d = lc/10$, where l is the length of the ... in feet and c is the change in curvature per chord ...rees. The other deflections may be found by the slide ...ule from the relation that the deflections vary as the ...uares of the distances from the $S\,T$.

...y setting the index of the slide of the slide-rule op... the value of d on the A-scale of the rule, the de... for any other point on the transition curve is ... on the A-scale opposite the distance on the C-scale ... rule. This distance is from the $S\,T$ to that point ... is in chords. It is assumed that the ordinary Mann... rule is used. The ease with which the computation ... can be appreciated from a trial.

E. R. Cary.

Rensselaer Polytechnic Institute, Troy, N. Y., Nov. 19, 1910.

Total Excavation and Concrete Laying on Panama Canal through October, 1910.

According to the latest report from the Isthmian Canal Commission the total and itemized excavation useful to the present Panama Canal is as follows:

Excavated by French Companies	78,146,960
French excavation useful to present Canal	29,908,000
Excavated by Americans:	
Dry excavation	75,344,412
Dredges	45,955,509
Total to Oct. 31, 1910	121,299,921
May 4 to Dec. 31, 1904	243,472
Jan. 1 to Dec. 31, 1905	1,799,227
Jan. 1 to Dec. 31, 1906	4,948,497
Jan. 1 to Dec. 31, 1907	15,765,290
Jan. 1 to Dec. 31, 1908	37,116,735
Jan. 1 to Dec. 31, 1909	35,096,166
Jan. 1 to Oct. 31, 1910	26,330,534

TOTALS BY DIVISIONS AND AMOUNT TO BE EXCAVATED.

Divisions.	Amount excavated.		Remaining to be excavated.	
Atlantic:				
Dry excavat'n	7,483,676	28,087,999	789,378	15,269,346
Dredges	20,604,303		14,479,968	
Central:				
Culebra Cut	54,484,979	64,913,538	29,701,745	32,211,480
All other p'nts.	10,428,559		2,509,735	
Pacific:				
Dry excavat'n.	2,947,198	28,298,384	3,432,944	13,737,019
Dredges	25,351,186		10,324,075	
Grand totals		121,299,921		61,237,845

It will thus be seen that of the present estimated 212,545,766 cu. yds. which were to be taken from the Isthmus to make the final prism, the French took out 14%, the Americans have taken out 57% and there remains to be excavated 29%. Of the 182,537,766 cu. yds. the Americans had to remove, some 67% had been accomplished. It should be noted that the total estimated required excavation has been increased from time to time to care for the slides which could not be anticipated in exact amount, but it is thought that the present estimated total is now sufficient to include all such future slides.

The immense amount of concrete that is being put into the canal structures is well shown by the following account covering the full period of concrete laying—Aug. 1909 through Oct. 1910:

CONCRETE DEPOSITED ON PANAMA CANAL.

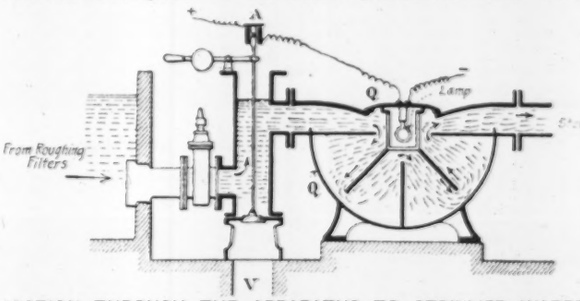
Gatun Locks	847,160	cu. yds.
Gatun Spillway	102,621	" "
Pedro Miguel Locks	371,721	" "
Miraflores Locks	52,199	" "
Miraflores Dam	321	" "
Total	1,374,022	cu. yds.

This average of somewhat over 90,000 cu. yds. per month is being passed now, the average for the last three months being 158,160 cu. yds. per month.

Sterilization of Polluted Water By Ultra-Violet Rays at Marseilles, France.

In our issue of Sept. 15, 1910, p. 275, Mr. Kenneth C. Grant described the tests that had been carried out at the Sorbonne, at Paris, to perfect a practical application of the sterilizing effect of ultra-violet rays to the purification of polluted water and mentioned the fact that at Marseilles, France, an experimental plant was being operated preliminary to a final installation for the purification of the city's water supply. In Le Genie Civil, Nov. 5, 1910, there is a description of this Marseilles plant and some figures on the operation which form a very interesting addition to the limited literature of this subject.

The city of Marseilles, about a year ago, opened a competition to various mechanical filtration concerns by the conditions of which tests were to be made in the city, open to the inspection of the city's engineers, and at the end of the specified tests the city was to decide which method it proposed to install for the purification of its water-supply. The provisions of this competition were that each company should establish at its own expense an installation of its system of sufficient size to purify 200 cu. m. (52,840 gals.) of water every 24 hrs.



SECTION THROUGH THE APPARATUS TO STERILIZE WATER BY ULTRA-VIOLET RAYS USED AT MARSEILLES, FRANCE.

As a result of this competition, the ultra-violet ray system, installed by the Westinghouse-Cooper-Hewitt Co., of Paris, with a preliminary treatment through the Puech-Chabal roughing filters was accepted. This system is the same as was described in our previous article, but the improvements worked out in the Marseilles' test plant resulted in a greater efficiency than reported then.

The process of sterilization by ultra-violet rays consists in exposing the water to be treated to the ultra-violet rays from a quartz-tube mercury arc lamp, so located as to penetrate all the water which is to be treated. The sterilization is accomplished through the destructive action of the rays upon any micro-organisms which may be found in the water. In the plant installed at Marseilles the water is first run through a set of Puech-Chabal roughing filters* which remove the material particles from the water and clear it up to such a state that only the micro-organisms have to be removed to give a pure water.

The accompanying figure shows a section through the ultra-violet ray sterilizer which was used in the test and which is practically the same as the unit, a number of which will be installed in the final plant. This unit will sterilize at least 600 cu. m. (158,520 gals.) per 24 hrs. by means of one lamp of the "Westinghouse-Silica" type, with a capacity of 220 volts, 3 amps. In this apparatus the lamp L is enclosed in a box Q, through which the clarified water from the roughing filters runs. This box is, as will be noted, provided with baffle plates, which cause the water to pass by the lamp at least three times, so that there is assurance that every particle of the water will be within the range of the ultra-violet rays some time during its passage through the semi-circular box. The lamp itself is separated from the water by a box with three windows of quartz glass, which has the property of absorbing only a negligible minimum of the ultra-violet rays thrown out from the mercury arc lamp. The valve S is controlled by a magnet A, so that if for any reason the lamp L is extinguished the valve S is dropped and the water from the roughing filters falls through the pipe V back into the reservoir from which it came. This valve is provided so that by no chance can the merely clarified water run through the sterilizer out into the mains, which should contain only sterilized water.

*These filters were described in Eng. News, March 26, 1908, p. 328.

This apparatus through a one month's test regularly passed at least 600 cu. m. of water in 24 hrs., at an expenditure of 26 W.-hrs. per cu. m., which equals 1 KW.-hr per 10,000 gals. At the rate of 10 cts. per KW.-hr., this would make the cost of sterilization about $10 per mil. gals.

Mr. Grant's article stated that in the tests at the Sorbonne the water passed through the apparatus there used at the rate of 1,270 cu. ft. per hr., and that the lamps used 1.32 KW.-hrs. The apparatus, therefore, gave sterilized water at the rate of 960 cu. ft. per KW.-hr. The improved apparatus used at Marseilles had one lamp using 0.66 KW.-hrs., which gave 880 cu. ft. per hr., so that the improved apparatus had a discharge of 1,330 cu. ft. per KW.-hr., nearly 40% better than the first tried apparatus.

Daily tests were made to determine the degree of sterilization the device could accomplish, and the accompanying table will show the results from eight typical tests. Examination was made of the amount of B. coli per liter and also of a number of other bacilli per cu. cm. both before and after treatment.

NUMBER OF BACTERIA IN MARSEILLES WATER BEFORE AND AFTER TREATMENT BY ULTRA-VIOLET RAYS.

Before		Test No.	After	
B. coli per liter.	Bacilli per cu. cm.		B. coli per liter.	Bacilli per cu. cm.
...	100	1	..	0.8
150	240	2	0	2.0
...	20	3	0	1.0
500	37	4	0	0
50	48	5	0	0
50	23	6	0	2
200	29	7	..	4.2
750	51	8	0	0.2

ROLLED STEEL CAR WHEELS have been adopted for the Chicago street railways. They have a much longer life than cast-iron wheels, are of less weight than the 570-lb. iron wheels, are less liable to have the flanges broken, and rarely develop the flat spots which were so objectionable in the iron wheels. When such spots so develop they are soon rolled out automatically in the operation of the car. The standard steel wheel, as developed by the Board of Supervising Engineers and adopted by the companies, is 34 ins. diameter on the tread, 3¾ ins. wide over tread and flange, and weighs about 525 lbs. with rim 2¼ ins. thick, or 200 lbs. with a rim 1⅞ ins. thick. The width is ¼-in. less than that of the iron wheels, and the depth of flange is reduced from ⅝-in. to ⅝-in. The chemical composition is so adjusted as to make the metal slightly softer than that of the rails, so that the wear will come largely upon the wheels, thus increasing the life of the rails.

CLEANING PAVEMENTS BY FLUSHING is opposed by the City Engineer of Charleston, W. Va., Mr. W. A. Hogue. In a report to the Board of Affairs of Charleston, on Nov. 9, Mr. Hogue says:

I am pleased to note that the authorities are opposing the method of cleaning pavements by the use of water under high pressure from flushing machines or fire hose. The damage that necessarily will follow to all classes of pavements in the city by the use of this method of cleaning pavements is obvious.

Most of your pavements are brick. After the flusher has passed over the pavement several times and the gutters are clear of water, there can be found lying in the gutter clean sand and particles of brick. The fact is that the filler is being washed out and the edges of the brick exposed, subjecting them to a severer test from traffic or abrasion, with the result that they are gradually wearing away. The same holds good to a large degree as to other classes of pavements. The continual wetting and washing takes the sand and fine materials from the composition, and it may be expected sooner or later to go to pieces.

Again, the filth is washed into the catch basins, oftentimes stopping them and causing the streets to be flooded, the sediment having to be removed at a greater cost than if taken from the street.

I would recommend the "Hand Patrol" or "Block System" of street cleaning through the day, supplemented by machine-broom cleaning at night, preceded by a very light sprinkling just enough to lay the dust, but not to convert in into mud.

Conveying and Depositing Concrete by Gravity Chutes.

For handling and distributing concrete and delivering it into place in the forms, various arrangements of wheelbarrows, trucks, cars and elevators are used, while conveyors have been used in some cases. A method of an entirely different character is that of raising the concrete to an elevated point and then distributing it to the forms by inclined chutes, through which the concrete slides by gravity. This method has been employed on a number of works of varying character, and has been made a specialty by the Concrete Appliances Co., of St. Louis, Mo., and Los Angeles, Cal. While the method is used by other firms, this company has developed and patented special apparatus and appliances for the conveying and distributing of concrete by gravity. Mr. H. W. Bryson is President of the company, and Mr. C. W. Ellis is Manager. We are indebted to them for plans and information.

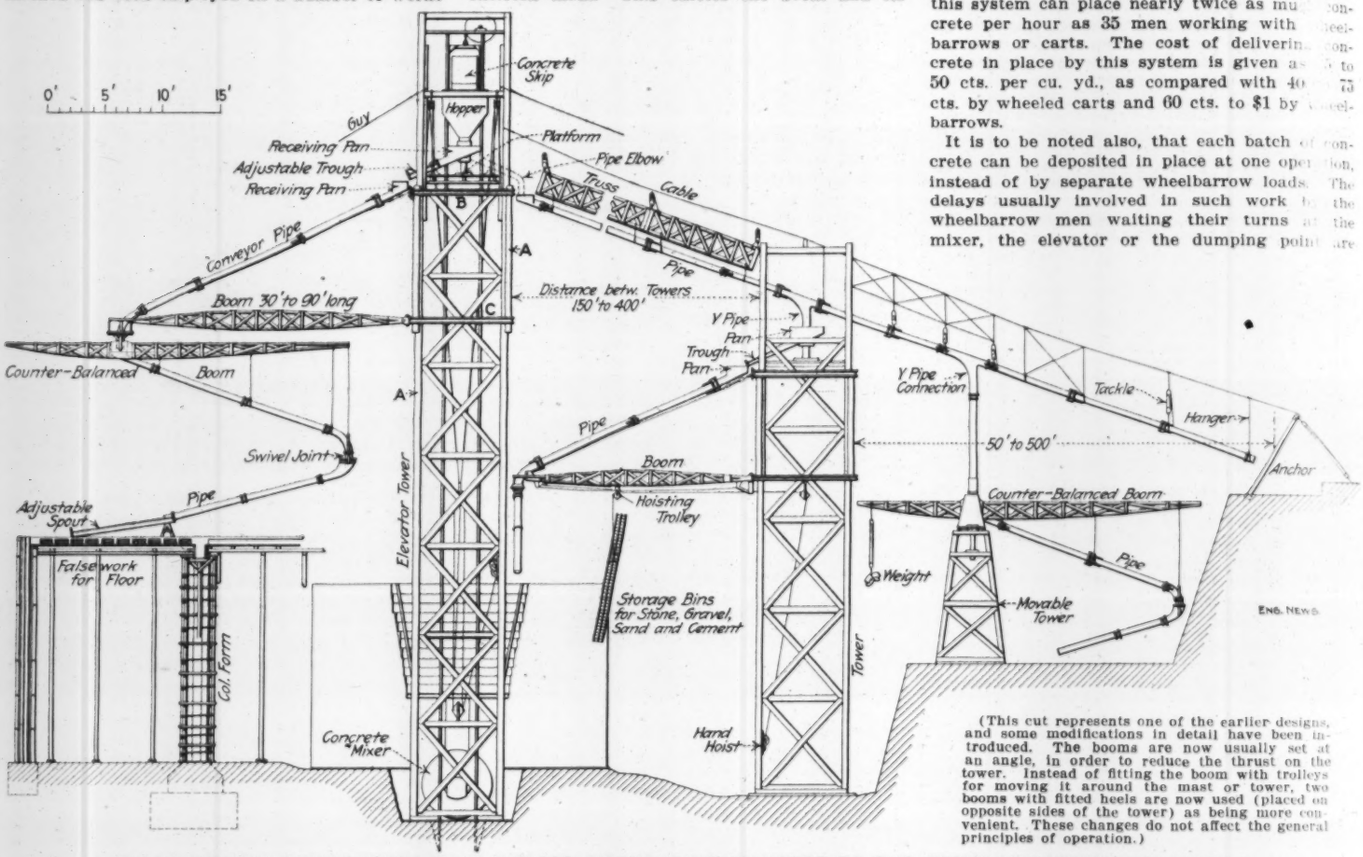
A typical arrangement of the plant on this company's system is shown in Fig. 1, but the booms are now set at an incline, to reduce the thrust on the tower. The elevator tower (rectangular or triangular in plan) is erected on a convenient part of the site. The concrete from the mixer is delivered directly into the automatic dumping skip, and at the top of the tower it is discharged into a hopper. From the bottom gate of this hopper it is discharged as required into a swiveling pan, and flows from this through a chute or an elbow to receiving pans on the upper ends of the inclined conveyor pipes. These pipes are supported by booms, which also carry hoisting trolleys for handling the forms, etc. The pipe may end in a vertical drop spout for filling column and wall forms, or it may have a swiveling adjustable inclined spout for distributing the concrete over a wide area such as a floor surface. By this flexible piping system the concrete can be delivered close to or at a distance from the elevator tower, and it is stated that it can be delivered in this way to a distance of 500 ft. For long distances, the pipes may be suspended from overhead cables and supported by intermediate towers. The various arrangements mentioned are shown in Fig. 1, but for each job they are modified or adapted to suit the plan of the site and other conditions.

Means are provided for conveniently raising the hopper and pipes as the work progresses. Four vertical timbers (A), fitted against the posts of the tower and connected by the upper and lower trolley tracks (B) and (C), form a skeleton mast. This carries the boom and its guys, so that the mast and boom form a complete unit which can be raised by block and tackle as the height of the tower is increased. On some of the earlier work the boom step and guy were carried by trolleys, so that they could be moved to any side of the mast or tower. The moving was found to be inconvenient, however, and two booms are now fitted on opposite sides. The cage carrying the main hopper and receiving pan can also be raised by tackle. For buildings of small area, no booms are required, the pipes being slung directly from the tower by cables. The eight-story Luckenbach Building, 32 × 68 ft., at Los Angeles, Cal., was built in this way.

There appears to be no trouble in the way of separation or segregation of the materials as the concrete slides down the pipe chutes. In fact, it is claimed that the churning motion in the pipes serve to agitate and mix the concrete during its travel; with his agitation and the speed of movement there is no opportu[illegible] for the concrete to be at rest and begin to s[illegible]

Among the advantages claimed are ra[illegible]y of work and a reduction in the amount of l[illegible] required. The force for ordinary work [illegible] include 2 men at the material bins, 1 at th[illegible]xer, 1 at the hoist, 1 at the cage at the to[illegible] the tower, and 2 men handling the end of [illegible] discharge pipe; (for each additional pip[illegible]here will be 2 more men). It is said that w[illegible] this force of 7 men, from 35 to 40 cu. yds. [illegible]concrete per hour can be mixed and depos[illegible]d in place. It is stated further that 10 men [illegible]nder this system can place nearly twice as mu[illegible]concrete per hour as 35 men working with [illegible]heelbarrows or carts. The cost of deliverin[illegible]concrete in place by this system is given as [illegible]to 50 cts. per cu. yd., as compared with 40 [illegible]75 cts. by wheeled carts and 60 cts. to $1 by [illegible]heelbarrows.

It is to be noted also, that each batch of concrete can be deposited in place at one operation, instead of by separate wheelbarrow loads. The delays usually involved in such work by the wheelbarrow men waiting their turns at the mixer, the elevator or the dumping point are eliminated by this direct handling and distribution of the concrete. Other advantages are that large quantities can be handled quickly, the concrete in place is dense and homogeneous, the floor space is left unobstructed for the use of carpenters and other workmen, and damage to floors, etc., by wheeling over them, is avoided. The method is applicable to concrete and reinforced-concrete structures of all kinds.



(This cut represents one of the earlier designs, and some modifications in detail have been introduced. The booms are now usually set at an angle, in order to reduce the thrust on the tower. Instead of fitting the boom with trolleys for moving it around the mast or tower, two booms with fitted heels are now used (placed on opposite sides of the tower) as being more convenient. These changes do not affect the general principles of operation.)

FIG. 1. TYPICAL ARRANGEMENT OF PLANT FOR DISTRIBUTING CONCRETE TO THE FORMS BY GRAVITY PIPE CHUTES.
(The Concrete Appliances Co., Los Angeles, Cal., owners.)

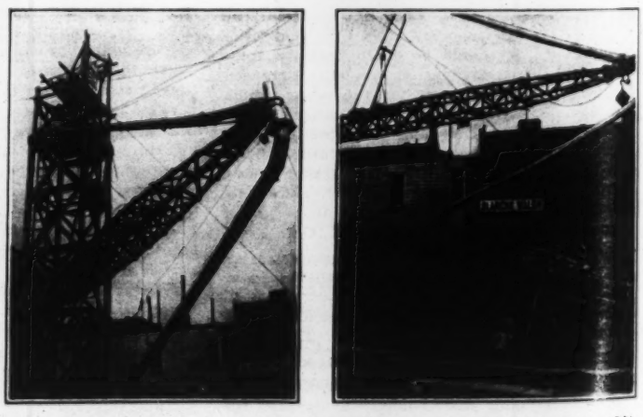


FIG. 2. DELIVERING CONCRETE BY PIPE CHUTES AT THE UNION LEAGUE BUILDING; LOS ANGELES, CAL.

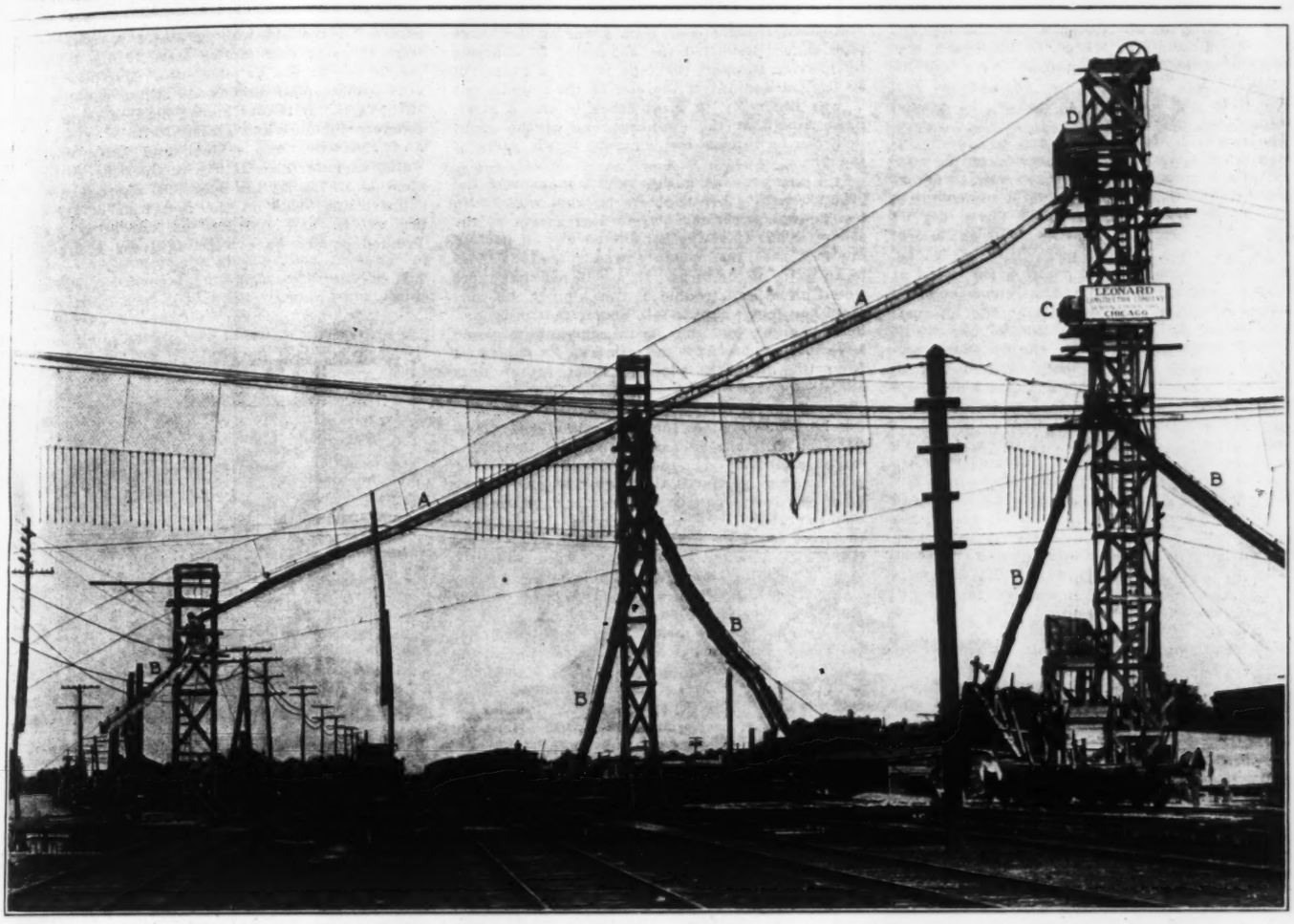


FIG. 3. TOWERS AND TROUGHS FOR DISTRIBUTING CONCRETE BY GRAVITY ON TRACK ELEVATION WORK AT GRAND CROSSING (CHICAGO); ILLINOIS CENTRAL RY.

In building the State Normal School at San Jose, Cal., three main elevator towers and seven auxiliary towers were used, with seven pipe lines. Each distributing system averaged 250 cu. yds. of concrete per day. This building is about 246 × 472 ft. The system was used also for the Atchison, Topeka & Santa Fe Ry.'s cooling house for refrigerator cars at San Bernardino. This has a total length of 1,212 ft., a width of 132 ft. and a height of 42 ft., containing some 6,500 cu. yds. of concrete. For this work there was a main tower 172 ft. high, with two auxiliary towers 302 ft. from it. The conveyor pipe was hung from a cable supported by the towers, and the auxiliary towers carried 70-ft. booms for the distributing pipes. The concrete was delivered by gravity for a distance of 502 ft. At the Trinken Building in San Diego, Cal., the 8-in. pipe was carried inside a 50-ft. box lattice boom built of four angles connected by lacing bars. Elbows or branches could be connected at any point along the boom, the spaces between the lacing bars being wide enough to admit of these branches. On this building, 250 cu. yds. of concrete were mixed and placed in 8-hour shifts.

Fig. 2 shows two views of the work on the Union League Building at Los Angeles. This is a reinforced-concrete structure 100 × 180 ft., nine stories high, with about 6,000 cu. yds. of concrete. For the piers and foundations it took only five men to deliver in place 35 cu. yds. per hour; this was the entire force for charging and operating the mixer and distributing the concrete. For the columns and floors from 7 to 8 men were required. The view at the left shows the elevator tower, main boom and delivery pipes. The view at the right shows the concrete being deposited in the restricted space beneath the inclined driveway.

The gravity system of the Concrete Appliances Co. has been adopted for the new work on the Sweetwater Dam (near San Diego, Cal.), which will include about 18,000 cu. yds. of concrete and will cost about $175,000. The system was used also in building the Seventh St. reinforced-concrete arch bridge at Los Angeles, but in this case two inclined open troughs were used, sloping in opposite directions and fed at the upper end from a spout projecting from the elevator tower at one side of the work. All the works mentioned above have been done under the company's system, and many of them were built by the F. O. Engstrum Co., of Los Angeles.

Other Cases of the Distribution of Concrete by Gravity

As mentioned already, the method of distributing concrete by gravity by means of inclined chutes has been used by other firms than the one whose special system is described above. In most of these cases, however, open troughs instead of pipes appear to have been used for chutes. An interesting example is the recent construction of retaining walls and bridge abutments for the track elevation work of the Illinois Central Ry. at Grand Crossing (Chicago). This

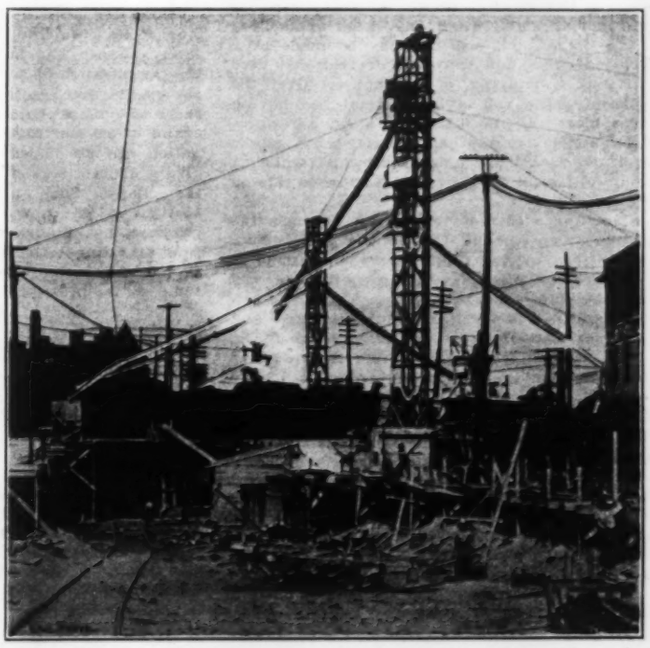


FIG. 4. DISTRIBUTING CONCRETE BY GRAVITY IN TROUGH CHUTES AT THE TRACK ELEVATION WORK AT GRAND CROSSING (CHICAGO); ILLINOIS CENTRAL RY.

work was done by the Leonard Construction Co., under the direction of Mr. F. L. Thompson, Engineer of Bridges and Buildings. We are indebted to Mr. Thompson for photographs and particulars, and Figs. 3 and 4 show the general arrangement of the plant.

The concrete mixing plant and 6 × 6-ft. elevator tower were placed at one side of the railway, and a main chute (A) was extended across the six tracks, being supported by a second tower between the tracks and a third tower beyond them. From each of the three towers lateral chutes (B) were run parallel with the tracks. The lateral chutes on the main tower were at a lower elevation than the main chute and the concrete for these was dumped at the intermediate hopper (C) instead of at the hopper (D) at the top of the tower. The chutes were rectangular troughs 12 × 12 ins., made of No. 16 galvanized sheet steel, with a 1½ × 2-in. angle on each edge. They were in lengths of 10 ft., suspended in wire loops attached to a pair of ⅝-in. cables. The inclination of the main chute was about 25° and that of the lateral chutes about 5 on 12. In Fig. 3, the tracks are elevated, and the concreting is being done beneath them. Fig. 4 shows one of the lateral chutes leading to the form for a bridge abutment.

For delivering the concrete directly into the forms, the end of the chute was fitted with a flexible pipe consisting of telescopic sections 15 ins. long, the diameter reducing from 10 to 8 ins. For part of the work, the chutes delivered the concrete into wheeled carts. Much of the concreting was done at the rate of 30 cu. yds. per hour. The concrete was made with gravel, and there was little, if any, trouble on account of separation of the materials in traveling down the chutes.

A somewhat similar method was used in the construction of the Grand Ave. viaduct for the city of Milwaukee, Wis.; this is a reinforced-concrete structure nearly 2,100 ft. long, having arches of 60, 80 and 145 ft. span. Instead of one mixing plant, however, there were several plants erected along one side of the work, each with a mixer and an elevator tower with a skip dumping automatically into a hopper. From the gate of the hopper the concrete was discharged into a swiveling trough feeding any one of three galvanized iron chutes supported on light timber falsework. These chutes had an inclination of about 1 on 3. In one instance the total distance traveled by the concrete was 300 ft. There was no apparent segregation of the materials, but men were stationed at intervals to keep the concrete moving and prevent any check to its flow. In this connection, mention may be made of a combined chute and conveyor devised and used by Mr. S. Coddington, of Milwaukee. Over the V-shaped chute was a longitudinal bar having blades hinged to it. This was given a reciprocating motion, so that on the down-hill stroke the blades forced the material forward, while on the up-hill stroke they swung up so as to ride on the concrete.

In erecting a concrete building in Chicago, the Falkenau Construction Co. used a main chute 14 × 18 ins., with auxiliary movable sections in 13-ft. lengths. All these were open troughs, and the main chute extended from an elevator tower. The company states that the minimum and maximum angles of the chutes were about 8° and 25° respectively. So far from the travel of the concrete in the chutes having any tendency to cause segregation, it appeared rather to mix the concrete more thoroughly.

The distribution of concrete by spouting was used in building the new plant of the American Sheet & Tin Plate Co., at Gary, Ind. This case is of interest and differs from the other works mentioned in that a portable mixing and elevating plant was used. We are informed by Mr. John M. Davidson, Resident Civil Engineer of the company, that the plant used for this purpose by the contractors (the Raymond Concrete Pile Co., of Chicago) consisted essentially of a 1½-yd. mixer mounted on a flat car and dumping into a bucket which was raised by an electric hoist to a height of about 70 ft. The bucket was then dumped automatically, the concrete falling into a hopper and passing thence along a steel-lined trough to an 8-in. swinging discharge pipe which permitted the depositing of concrete by gravity through the pipe within a radius of 50 ft. On account of the size of the foundations it was necessary in most cases to use a steel-lined trough at the discharge end of the spout in order to convey the concrete to all parts of the form.

The concrete was mixed very wet, as was the practice with other concrete on this work. No trouble was experienced from segregation of the concrete, but this was considered due in part to the fact that the concrete was spread by hoes to all parts of the form. It is believed that there would have been trouble of this kind if the concrete had laid where it fell, and if the forms had been narrow, but that such segregation would have occurred when the concrete was falling from the discharge pipe or spout rather than during its travel in the trough. The angle of slope of the spout varied from 25° to 50° from the horizontal, as a rule the angle was about 35°. Choking occurred occasionally at the flatter slopes, and usually at the flared end of the spout pipe which received the concrete discharged from the upper trough. While very good results were obtained with this portable arrangement, the time required to shift the machine detracted from its efficiency. It is considered that the most satisfactory work with the spouting process would be in cases where a great volume of concrete is placed from one position.

A very similar method has been used in building the retaining walls for the approaches to the Detroit River tunnel. In building the approaches to the La Salle St. tunnel under the Chicago river, the work is done in open cut for the length of one block at each end of the work. Here the concrete mixer is placed at the edge of the cut (traveling along as the work progresses) and dumps the concrete directly into the head of a sheet iron pipe, the lower end of which has a movable section for delivering the concrete at any point within its reach. This method is used for the arches as well as for the walls.

The Collapse of the Reinforced-Concrete Henke Building, Cleveland, Ohio.

At 7 p. m. on Nov. 22, 1910, a four-story reinforced-concrete building being erected for the Henke Furniture Co. on the corner of Lorain Ave. and West 30th St., Cleveland, Ohio, suddenly collapsed, throwing one of the walls over on a two-story frame building next door, and so crushing the structure as to cause the death of four of its occupants and the serious injury of seven others. The failure was so complete and the complication of debris so great that nothing short of a most thorough examination and investigation can be hoped to give a definite reason for the collapse. Such an investigation is now in progress, but the results from it cannot be expected for some little time, so we present here a short account of the accident, procured for us by Cleveland engineers. When the final report is available we hope to be able to give that.

The building code of the city of Cleveland allows eight-story reinforced-concrete buildings, and a number of buildings from two to eight-stories testify to the safety and popularity of this type of construction. The building here described was designed by Searles, Hirsh and Gavin, and was being erected by the Forest City Construction Co. for the Henke Furniture Co., taking the place of a former building destroyed by fire. The old ruins were removed last July and a portion of the old west wall that remained was used in the new work (Fig. 1). This portion of the old wall is stated to have been from three to four stories high, 17 ins. thick in panels and 21 ins. at pilasters at first floor. The approximate plan dimensions of the building are 107 × 90 ft. It is four stories high, of reinforced-concrete columns and girders, with a hollow-tile and concrete floor system and brick curtain walls, varying from 21 ins. in thickness in basement to 13 ins. at top floor. It was designed to support live loads on the first floor of 125 lbs. per sq. ft. and 100 lbs. on the other floors. Twisted square bars were used for reinforcing in all but the columns, where plain, round bars were used.

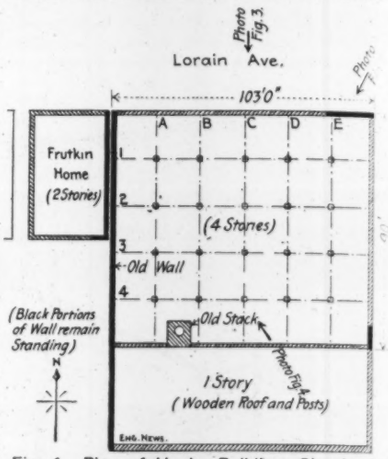


Fig. 1. Plan of Henke Building, Cleveland, O. Collapsed Nov. 22, 1910.

The building had been pushed rapidly and was practically completed on the day of its collapse. Reports differ as to the condition of the forms at that time, but testimony at the investigation seems to show that all the supports were in on the fourth floor, that is, the struts holding the roof, and that the supports for the fourth floor had been removed, and two shores consisting of two pieces of 2 × 4-in. sticks, spiked together and placed about 4 ft. apart under the beams had been substituted for the forms. The information so far obtained from testimony is quite contradictory. The testimony of the architect shows that the last pouring on the roof was made on Nov. 10, which would make that concrete twelve days old, and the last pouring on the fourth floor was on Oct. 18, making that concrete 35 days old. In spite of these dates, the testimony seems to show that the concrete was green and not thoroughly set in both of these slabs. The plans for the building had been examined and passed upon by the Building Department of the city, which has a reputation for being very careful in regard to this kind of work. Its facilities for sufficient inspection, however, are not so good.

FIG. 2. CONDITION OF COLUMNS.
(Columns indicated shown on Fig. 1.)

The debris of the collapse extended on four sides, blocking Lorain Ave. and reaching some

tance in other directions. A portion of the old t wall remains standing and a narrow piece the east wall on West 30th St. stood up and naced the traffic until pulled down. The ole block remained and was also razed subquently, as it endangered the dwellings south the one-story section. The only portion of e front wall on Lorain Ave. left standing is own in the accompanying photograph (Fig. 3), o piers and a lintel at the northwest corner. he photographs, Figs. 2 to 4, were taken after he razing of the portions of the wall noted bove. As seen in the photographs, most of the lumns remained to a height of from the first the third floor level, with a general inclination stward.

mmediate action was taken to investigate and the blame for the failure. Director of Public Safety Hogen requested the Builders' Exchange, the Cleveland Engineering Society and the Cleveland Institute of Architects to send two representatives each to serve on a board of inquiry, and they began their work the next morning with the following membership: H. B. Briggs, of Briggs & Nelson, and V. E. Thebaud, of Tousley & Thebaud, representing the Institute of Architects; J. C. Skeel, Vice-President of Skeel Bros. Co., and J. R. Gloyd, Superintendent of the Crowell & Sherman Co., representing the Builders' Exchange; W. O. Henderer, Vice-President of the Osborn Engineering Co., and B. R. Leffler, Bridge Engineer of the Lake Shore & Southern Michigan Ry. Co., representing the Cleveland Engineering Society. This Board has been holding its meetings regularly and is expected to report soon.

As noted above, the engineers who have observed the site of the failure are somewhat reluctant to express any opinion as to its cause until all the testimony has been taken by the Board of Inquiry.

Fig. 3. Looking Southwest Toward Northeast Corner of Wall.

Fig. 4. Looking South Toward Middle of North Wall.

FIGS. 3-4. VIEWS OF THE RUINS OF THE HENKE BUILDING.

The Disposal of Trade Wastes.*

By GEORGE A. JOHNSON.†

The disposal of trade wastes is a problem of rapidly increasing importance. With the steady industrial growth of the country the question of what shall be done with the wastes of production becomes more and more a vital question. In the conservation of the purity of our streams and lakes the trade waste problem looms up as a factor, not in importance equal to the sewage problem, but one which every day is becoming more difficult of entirely satisfactory solution.

The manufacturer, constituting the financial backbone of the country's prosperity, is often inclined to the conviction that he should be allowed much latitude in all questions affecting the cost of production of his goods, and within all reasonable limits he should. But when such latitude becomes a license to destroy, or seriously affect, the purity and appearance of public waterways, from which the bulk of the water supplies of the country are derived, a halt must be called and remedial measures found and enforced.

The seriously complicating factor in the trade waste problem is the wide and sudden variation in the composition of the wastes, not only in different factories but in a single factory. It is impossible to lay down hard and fast rules to govern the degree to which all wastes must be purified before they are discharged, for the simple reason that each problem must be considered in the light of the surrounding conditions, and the remedial cloth cut to suit the local requirements.

Probably the most important feature requiring consideration is the amount of solid matter which the wastes contain, expressed not in the terms of the analyst as so many parts per million but more comprehensively as tons per day or per year. It might almost be said that if all trade wastes were to be treated before their discharge to the extent of removing the suspended solid matters the trade waste problem would be nine-tenths solved. Of course there are cases where spent dyes, for example, would render a stream unfit for use by some industries, and where large volumes of antiseptics in a clarified waste liquor which was allowed to enter the public sewer system, might seriously interfere with the treatment of the sewage at the purification works. But it nevertheless remains a fact that if such solids as dirt, hair, soap and grease, tar, wool, malt, etc. were first removed from the wastes, the resulting liquor in the vast majority of cases, would cause little if any trouble at the purification works; and except where the volume of such wastes is greatly out of proportion with the stream flow, the liquid wastes would speedily become purified and practically unobjectionable.

It is not possible or expedient to exclude from rivers the wastes of manufacturing industries. Some depreciation in the quality of the water in the stream is inevitable, but the use of moving bodies of water for trade waste disposal should be permitted to the greatest practicable extent so long as actual nuisance is avoided and where the public health is not endangered. It is fortunate that in the large majority of manufacturing wastes the element of danger coming from the presence in such wastes of pathogenic germs is usually at a minimum.

While on this point it may be well to mention the possibility of danger in the wastes coming from tanneries and wool scouring establishments. It appears that there is at least one case on record where anthrax was contracted by a man, the source of the infection presumably being water. A number of scientific articles have been written regarding the possible danger in the wastes from abatoirs and crematories, the claim being made that even tuberculosis germs are sometimes discharged from such establishments to constitute a menace to the public health where such wastes are discharged into streams used as sources of public water-supply. Such assumptions as these appear to be pretty far fetched, and as a general proposition it appears to be almost certain that the trade waste problem has little to do with the causation of water-borne diseases.

Under practically all circumstances the disposal of trade wastes means their discharge into the nearest waterway or into public sewer systems. In the latter case the question arises: To what degree must such liquors be purified before they may properly be admitted into the public sewers? As a rule this means the removal by the manufacturer of the suspended solid matters in the wastes. As already stated these matters undoubtedly represent the greatest objection to the discharge of such wastes into public sewers or public waterways. There are cases, however, where certain germicides present in the wastes affect prejudically the subsequent purification of the domestic sewage with which the wastes are mixed in the sewer.

Permission for the manufacturer to discharge his wastes into public sewers may be hedged in by a number of provisions which offer many opportunities for varied interpretation by the different parties interested. In general these are that the wastes shall not injure the sewer, that is, contain substances which will actually injure the structure; further, that the wastes shall not affect prejudicially the subsequent purification of the sewage, meaning by this that they shall not add abnormally to the solid content of the sewage, or to its content in grease, tar products, etc., or contain germicides which will destroy such bacterial life as is absolutely necessary for the proper and efficient purification of the sewage by artificial methods; and finally, and perhaps most important of all, that the trade wastes shall not abnormally affect the capacity of the sewer.

Taking these points up in order, it appears that little apprehension need be felt with respect to the possible affect which any trade waste may have upon the sewer itself, so far as causing actual damage to the structure. It is true there may be cases where the wastes are so strongly acid that there may be brought about a disintegration of the structure, but such cases are rare.

The prejudicial effect which wastes may have upon the subsequent purification treatment is one which frequently requires some careful consideration, for the destruction of beneficial bacterial life precludes efficient purification by artificial methods. Wastes which contain arsenic, for instance, if such germicides are present in relatively large quantities, should be treated by the manufacturer before they are discharged into the sewer. A simple method of removing the arsenic is to pass the liquid through a layer of iron filings or coke.

Speaking broadly, trade wastes and domestic sewage are probably best and most economically treated together. When the complete purification of wastes alone is attempted many complications arise, for it may perhaps be stated as a general proposition that trade wastes are not amenable to biological purification.

Wastes which contain large quantities of solids like hair, lime, gas, tar, grease, distillery refuse and other similar wastes, should have such substances removed to the greatest practicable extent before the wastes are discharged into public sewers or into public waterways. Such solids, if allowed to enter the sewers with the liquid wastes, may produce clogging, and are almost certain to be a somewhat expensive proposition to remove at the purification works, especially if such works do not contain ample facilities for preliminary sedimentation.

The question of when trade wastes may be admitted into public sewers is a serious and difficult one to answer. In scattered urban and rural districts the volume of trade wastes is frequently so great as to upset the whole sewerage system on account of the disproportion of the wastes to the sewage.

There are cases in connection with the Passaic Valley Trunk Sewer project which are bound to become perplexing problems in this connection. The restrictions surrounding the construction of this immense sewer require that each community be permitted to discharge trade wastes into it with its domestic sewage only to the extent of 10% of the total volume of the sewage of the community.

There are a number of communities to whom this restriction if rigidly lived up to will mean much. In at least one community the trade wastes amount to 90% of the total volume of sewage discharged by it. If this restriction is enforced, as appears inevitable and unavoidable, it means that those communities wherein the volume of trade wastes is greater than 10% of their total discharge must devise ways of separating from their wastes such as are actually prejudicial to the quality of the water in the Passaic River; and if the residual trade wastes amount to more than 10%, as in a number of instances they will, then such communities or the manufacturers located therein, must themselves care for the balance in separate purification works before they may be discharged into the Passaic River.

It is a difficult problem to proportion the cost of a certain sewer to each user thereof. If the proportionment is on the basis of the actual volume of sewage which each user discharges into it the manufacturer, who is usually the biggest taxpayer, is the hardest hit and frequently will not only flatly refuse to pay such a proportion of the cost, but will even defend extended litigation in the courts intended to compel him to do so.

To what extent, and under what restrictions, may public waterways be used for the reception of unpurified

*Portions of a paper read before the New Jersey Sanitary Association, at Lakewood, N. J., Dec. 3, 1910.

†Consulting Engineer, 150 Nassau St., New York City.

trade wastes? Obviously the public health must not be endangered; the flow in the stream must be sufficient at all times to speedily disperse and allow of the purification of such wastes to a degree where public and industrial water-supplies will not be affected prejudicially; and, finally, the wastes must not be of such composition that they will form unsightly and otherwise objectionable sludge deposits in the bed or on the banks of the stream. To live up to all of these requirements each problem must be considered by itself in the light of all the surrounding conditions. It is impossible to state a specific remedy to cover all cases.

An immense amount of research work on the details of treating specific wastes has been done by the State Board of Health of Massachusetts, and a good bibliography of the literature on the subject is given by Mr. F. A. Barbour in the September, 1909, number of the Journal of the Engineers' Society of Pennsylvania.

The Substitution of Electric Traction for Steam in the Boston Metropolitan District.

The installation of electric traction in place of steam in and about Boston has been frequently brought before the legislature and various commissions in very recent years and largely in connection with the attempts of the Boston & Eastern Ry. to secure the right to build a high-speed electric line from the northeastern suburbs to Post Office Square (as noted in Eng. News, Aug. 20, 1908, p. 196; Nov. 5, p. 504; Dec. 10, p. 644). In February, 1910, a joint board made up of the Massachusetts Railroad, the Boston Transit, the Metropolitan Park and the Harbor and Land Commissions reported to the Legislature on the commercial and transportation aspects of the improvement of the Boston metropolitan district, and in accordance with the directions of the General Court in 1909. (See Engineering News, Feb. 10, 1910, p. 154.)

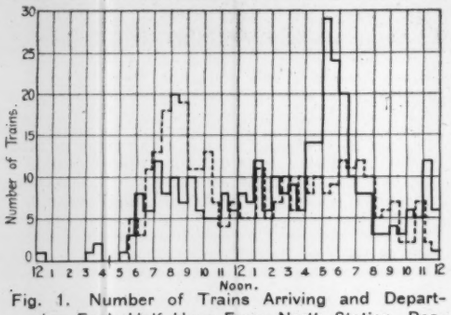


Fig. 1. Number of Trains Arriving and Departing Each Half Hour From North Station, Boston. (June 20, 1910.)

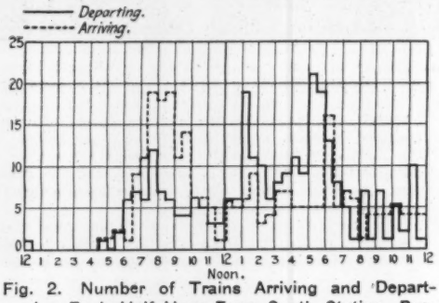


Fig. 2. Number of Trains Arriving and Departing Each Half Hour From South Station, Boston. (June 5, 1910.)

It was reported that the suggested improvements in the railway service of this district were predicated on the substitution of electricity for steam. It was recommended that the Legislature require all railroads in the district to report on the possibility of the change. The Legislature made such a direction and named the Joint Board on Metropolitan Improvements, before mentioned, to receive the reports.

The reports of Mr. A. H. Smith, Vice-President and General Manager of the Boston and Albany R. R., and of Mr. E. H. McHenry, Vice-President of the New York, New Haven & Hartford R. R., were submitted on Oct. 31 and made public a few days ago. These reports are given in abstract in what follows.

Report of the New York, New Haven, & Hartford R. R.

It was quite impossible to devote the proper degree of study and investigation to this subject within the very brief time set by the Legislature, which the magnitude and complexity of the problem demand, but a special effort has been made to present at least the salient features of the proposed electrification of railroads within the Metropolitan District, together with an approximate estimate of the cost, in order to comply as fully as possible with the terms of the resolves of the last Legislature.

The investigation of the traffic conditions of the New York, New Haven & Hartford and the Boston and Maine Railroads has been completed by Mr. A. B. Corthell, Consulting Engineer, to whom the task was assigned, which included a study of the train service upon some 20 through lines and branch lines, together with analyses of the number and direction of trains operated, train schedules, tonnage, speed and terminal conditions.

To Mr. W. S. Murray, Electrical Engineer, was assigned the task of analyzing the traffic data and the preparation of estimates of the cost of the necessary power-houses, overhead equipment, tracks, and electric engines and multiple-unit equipment required to replace the present steam engines and passenger cars.

RESULTS OF STUDY.—The results of these investigations are appended as follows: Figs. 1 and 2 show the number of trains in and out of the North and South Stations each half hour, and illustrate the relative amount of traffic in each direction at different hours of the day. As a matter of interest, the number of passengers in and out of the two stations, together with similar data for the Grand Central Station at New York for the past ten years is added (Fig. 3). The curve of future growth may be approximated by extending the curves on this diagram.

Fig. 4 shows curves of train weights, including motors, moving each period of ten minutes throughout the day of 24 hours on both the N. Y., N. H. & H. R. R. and B. & M. R. R.; also the estimated power-house requirements.

In Tables I. and II. are equipment estimates showing the amount of electrical equipment necessary to cover the service between Boston and the suburban terminals. These estimates show both the number of electric engines required to perform all service (or as an alternative, the number of electric engines required for the operation of through trains only) and the number of motor and trailer cars, operating in multiple-unit service, required to replace the present trains terminating within the electric zone.

A study of the number of steam and electric engines, or their equivalent multiple-unit cars, at all suburban termini (15 on both the B. & M. and N. Y., N. H. & H. R. R.) for which it is necessary to provide electric or steam-engine facilities, shows that there are now in use 194 steam-engine stalls. With electrification, 111 steam-engine stalls will still be needed together with 103 electric-engine and 199 multiple-unit car stalls. This change, it is estimated, will cost $1,417,000.

Condensed estimates of construction cost within the Metropolitan District of Boston are given in Table III.

It is not believed that the maps, charts and statements as above, require an extended commentary, as they are practically self-explanatory. The estimates of construction cost are based upon the single-phase system of electric operation as in service between Woodlawn and Stamford on the New York division of the N. Y., N. H. & H. R. R.

This system employs a generating voltage of 11,000 volts with a frequency of 25 cycles. An installation of this kind, as proposed for the lines in the vicinity of Boston, will differ, however, in some very important particulars, as the complications and increased cost due to the dual operation of both the single-phase system of the New Haven Company and of the direct-current system of the New York Central Company will be avoided.

No substations will be required within the zone of electrification, and as all current will be taken from an overhead contact, no third rail for conducting current to engine shoes will be required. The elimination of the third rail is particularly desirable in this instance, as its introduction would create grave difficulties in working out plans for the equipment of the many and complicated track systems in terminal yards and at crossovers.

The estimates for main lines, sidings and yards have been considered upon passenger basis only, and do not cover freight and switching service.

The power requirements have been ascertained by applying to the computed ton mileage, an average coefficient derived from the experience of the New Haven Company on its New York Division from operation within its electric zone, which affords an estimate of the amount of energy required, expressed in terms of kilowatt hours.

This result has been equated by adding 50% for holiday conditions, 15% to include heating and lighting of local trains by electricity and 25% to cover transmission losses and power used for general auxiliaries, station and yard lighting, signaling, shop and other power requirements.

The estimate so obtained has been reduced by [illegible] the two-hour overload capacity of generators [illegible] final result that a normal generating capacity [illegible] KW. is indicated as required.

The estimates for transmission lines and the [illegible]head contact system cover the equipment of single an[illegible]ple main-track mileage and trackage in terminals, [illegible] and sidings, as follows: 15.46 miles of four-trac[illegible]; 128.07 miles of double-track routes; 32.44 miles [illegible]gle-track routes; 111.2 miles of yard tracks and sid[illegible]. The total mileage included in the above estimates [illegible]uiva-lent to 461.62 miles of single track.

The construction types of the overhead struct[illegible] and suspended system will be quite similar to those [illegible]alled on the New York Division of the New Haven C[illegible]any, subject to certain modifications and improvement[illegible] which our experience indicates should be made.

The necessity of changing from steam to electri[illegible] and vice versa at the limits of the electric zone, m[illegible]es it necessary to provide proper transfer facilities, fo[illegible]hich due provision has been made in the estimate.

It will be noted that this is a very burdenso[illegible] requirement in its effect upon both construction cost and operating expenses.

The equipment estimates attached to this report [illegible]ndicate that equipment must be provided for the operation of 14,630 daily train miles, based upon the summer schedule of 1910. This is the theoretical or time-table mileage, as compared with the total actual mileage including deadheading and helping of 17,286 miles.

The electric locomotives and multiple-unit equipment required to replace the present equipment in this service as given in the estimate include additions of 15% for shopping reserve and 50% for holiday service and contingencies.

The estimates for the complete equipment of the New Haven and B. & M. railroads as shown in greater detail in the attached summaries amount to $13,302,750 and $15,889,192, respectively, or $32,751,942 total for both companies.

It will be understood that these estimates are based upon a plan for electrification within the Metropolitan District of Boston in literal compliance with the request of the Legislature, which in no wise represents the scope and method of development which would naturally be favored by the railroad companies in interest. The proposed restriction of the operation to the Metropolitan District establishes limits which are purely artificial and arbitrary, having but little relation to the flow and volume of traffic, and makes necessary the establishment of costly intermediate terminals at some 13 points on the district boundaries for accommodating both steam and electric motors.

All trains passing through these transfer points will be subject to delays of three or four minutes in both directions, and, accordingly, the improved service within the Metropolitan zone will be gained only by sacrificing the commercial interests of many important secondary centers and outlying points, such as Marblehead, Salem, Lawrence, Lowell, South Framingham, Walpole, Brockton, Whitman and Greenbush, which communities will be less well served than at the present time.

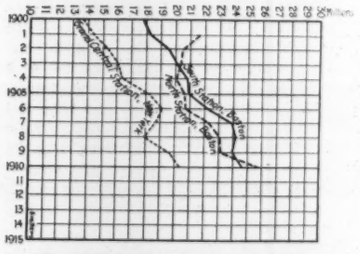


Fig. 3. Total Passengers In and Out of North and South Stations, Boston, and Grand Central Station, New York City; for the Year Ending June 30, 1910.

Similar conditions forced the extension of electric service on the New York Division of the New Haven Company to Stamford, and on the New York Central Lines to White Plains and Yonkers, although not required by the Act of the Legislature, as such further extensions were necessary in order to avoid the cost and delays incident to engine transfers within suburban limits.

These conditions lead to the conclusion that the subject requires a more complete and comprehensive study before fixing limits for the proposed electric service.

COMPARISON WITH NEW YORK.—The problem in its general nature is altogether different from the conditions at New York, as in the latter case the entire traffic of the N. Y., N. H. & H and New York Central Railroad companies within the city limits is concentrated upon a single four-track route between the Grand Central Terminal and Woodlawn, while on the contrary, at Boston the suburban business is diffused over a great area, requiring the equipment for electric operation of not less than twenty through routes and branches, with a corresponding effect upon first cost and operating charges.

Notwithstanding the more favorable conditions [illegible] New

York incident to the greater density of traffic and the smaller track system in the region served by the New Haven and New York Central railroads, the records of the New Haven Company demonstrate that under present conditions the electric train service not only fails to earn any interest upon the very large amount of capital invested, but that it has also increased the cost of operation, and with the less favorable conditions in the vicinity of Boston, it is impossible to escape the conclusion that the deficit in fixed charges and operating expenses will be still greater.

In explanation of this disappointing result, it may be stated that the experience of the New Haven Company in operating a mixed steam and electric service has proven very unsatisfactory. The annoyances and losses due to smoke, cinders, steam and noise are at best only alleviated without being eliminated; while at the same time so large a proportion of the expense of both methods of operation is retained as to prevent the realization of the fullest degree of economy of either system. This becomes more apparent when it is considered that the power stations if provided for passenger reqpirements only, will have a large unused capacity between the hours of peak load, which otherwise could be utilized to very good advantage for the transportation of freight, and more particularly as the occupation of tracks by passenger trains during the hours of peak load acts automatically to limit the simultaneous operation of freight trains at such times. Thus little or no additional investment in power-houses is required for freight operation, and similarly the overhead track equipment serves equally well for both passenger and freight traffic, which makes it practicable to extend electric operation to include all classes of service at the cost of only the additional engines and the equipment of yard trackage required for freight service.

It therefore seems quite safe to conclude that no general substitution of electric for steam traction should be made unless the substitution is complete, including passenger and freight operation and yard switching in addition, and also that in making such substitution the operation should be extended to include the full length of run or engine district, in order to avoid the uneconomical subdivision of the present "trains runs," together with the added expense and delays incident to intermediate engine transfer stations.

The extension of the estimates as given above, to include the very much larger expenditures required to cover the inclusion of freight service and yard switching, together with the probable enlargement of the limits of the electric zone, is not possible at this time, as the data for such estimates are not at present available, but it is certain that the revised and completed totals will be of the most imposing magnitude.

The electrification of the Boston suburban district would release large number of steam engines and passenger coaches, which should properly be credited to the construction estimate, but as there is no apparent opportunity for the utilization of so large an amount of equipment of this special type, and as its value for resale would be so doubtful, it is not practicable to assign values to this item.

It should also be noted that no account has been taken of the profound changes affecting terminal conditions and methods of operation, which would be introduced if the proposed connection between the North and South Stations at Boston is constructed, and if there is any reasonable probability of such construction being undertaken in the near future, the installation of an elaborate and costly electric system at the present terminals could not be reasonably considered.

In general it would seem altogether more practicable to at first restrict the substitution of electricity for steam to a few of the more important routes, subsequently extending the system as rapidly as consistent with the financial conditions and the public needs.

Respectfully submitted,

(Signed) E. H. McHenry, Vice-President.

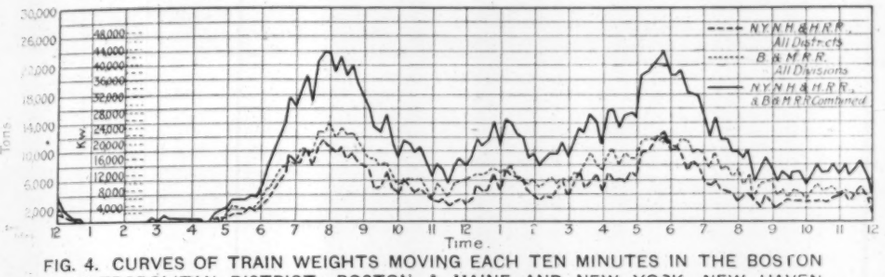


FIG. 4. CURVES OF TRAIN WEIGHTS MOVING EACH TEN MINUTES IN THE BOSTON METROPOLITAN DISTRICT; BOSTON & MAINE AND NEW YORK, NEW HAVEN & HARTFORD R. R.

TABLE I.—EQUIPMENT ESTIMATE FOR THE CONVERSION OF THE BOSTON & MAINE R. R. FROM STEAM TO ELECTRIC TRACTION, AT BOSTON.

Statement showing the amount of electric equipment necessary to cover the service between Boston, Swampscott, Wakefield Junction, Wilmington, Lexington, Wayland and Waltham, and the number of steam locomotives which can be released; also the number of coaches, by the use of multiple-unit equipment.

PASSENGER SERVICE:	
No. of locomotives required	98
No. of steam locomotives which can be released by substitution of electric locomotives	35
No. of electric locomotives required for switching service at passenger terminal	17
Switching engines released at passenger terminal by reason of electrification	17
Time-table engine mileage	7,853
Total engine mileage including deadheading and helping	9,854
No. of electric engines required to run trains coming from and going to points beyond electric zone	54
Time-table engine mileage	4,792
Total mileage, including deadheading	5,370
Multiple-unit equipment required to perform the service entirely within electric zone*	227
Time-table mileage	2,715
Car-miles made by motor cars	2,715
Car-miles made by trailers	8,145
No. steam engines released under m.-u. system	31
No. coaches released under m.-u. system	227

*Number of motors and trailers, assuming that one motor car will handle three trailers, seating capacity 75 each.

TABLE II.—EQUIPMENT ESTIMATE FOR THE CONVERSION OF THE N. Y., N. H. & H. R. R. FROM STEAM TO ELECTRIC TRACTION, AT BOSTON.

Statement showing the amount of electric equipment necessary to cover the service between Boston, Campello, Cohasset, South Braintree, Headville, Dedham, Mattapan and Needham Junction, and the number of steam locomotives which can be released; also the number of coaches, by the use of multiple-unit equipment.

PASSENGER SERVICE:	
Number of electric engines required to perform all service	64
Time-table miles	6,777.63
Total mileage, including deadheading and helping	7,431.88
Number of electric engines required to run trains coming from and going to points beyond electric zone	40
Time-table miles	3,956.56
Total mileage, including deadheading	4,737.76
Multiple-unit equipment required to perform balance of service:	
Motor cars	58
Trailers	67
Time-table miles	2,821.07
Car-miles made by motor cars	3,978
Car-miles made by trailers	6,430
Number of steam engines which can be released	53
No. of coaches released under this proposition	164

Report of the Boston & Albany R. R. (New York Central & Hudson River R. R. Co. Lessee.)

The lines for which the studies have been made consist of the four-track main line from a junction with the South Station to South Framingham, and the double-track Highland Branch of the Newton Circuit.

While the Grand Junction Branch, which extends from Cottage Farms to East Boston is also within the Metropolitan District, it has been excluded from the studies for the present, for the reason that no regular passenger service is performed upon the Branch, the only train movements of that character being infrequent special movements for the interchange of special cars between roads, or for an occasional emigrant train in connection with steamship service.

The Newton Lower Falls Branch, which is also within the District, is now electrified.

While the Resolve of the Legislature does not impose any duty to make studies beyond the Metropolitan line, which intersects the Boston & Albany R. R. main line at Lake Crossing, about 16.2 miles from the Boston Terminal it has been necessary, on account of operating and financial conditions, to continue the studies to South Framingham, where a more suitable location is obtainable for engine terminals, and also to avoid the necessity of having engine terminals both at South Framingham and at the Metropolitan Line. This extension adds about five miles of main line to the studies required.

There has also been embraced in the studies, while not specifically required by the Resolve, the electrification of some of the sidings and local freight stations on the main line, between Cottage Farms and Kneeland St. yards. It is assumed that the purpose of these studies is to ascertain the difficulties which will be encountered in the elimination of the noise and smoke from steam locomotives from the densely populated area of Boston, and the purpose, therefore, would not be accomplished without considering the electrification of the freight engines employed in handling freight upon these particular sidings and yards.

The track mileage involved in the above electrification is substantially as follows:

Boston to South Framingham, four tracks	83.6 miles
Highland Circuit, two tracks	19.78 "
Yards and sidings	25.00 "
Total	128.38 miles

Particular attention is called to the fact that no studies are submitted for the electrification of the South Terminal. The result must be added to the Boston & Albany R. R. report, as the latter company will doubtless have to bear its proportion of the additional capital and operating expenses involved.

TRACK AND STATION CHANGES.—In making studies involving the electrification of the foregoing tracks, it has been deemed wise to assume that certain changes would first be made in the main track and station arrangements to place all local trains upon the outside tracks, and the high-speed trains on the inside tracks, and thus to make it unnecessary for passengers to alight from trains upon tracks which are under operation, which might be quite undesirable for a material increase in traffic, as well as on account of the numerous electrical appliances which would be introduced in the track structure. This change in the method of operating the tracks will, of course, necessitate some changes in the station buildings, platforms, overhead bridges, subways, etc.

These changes are so intimately associated with the studies that they cannot be ignored, and while they might ultimately be made desirable by a large increase in the operation under steam traffic, they would be immediately precipitated by the adoption of electricity, and it is necessary to consider at this time the cost of the work as a part of the general plan.

ELECTRIC SYSTEM.—There would be a main power house in Beacon Park Yard, with three substations, lo-

TABLE III.—SUMMATED COSTS OF PROPOSED TRAFFIC CHANGES; BOSTON METROPOLITAN DISTRICT.

N. Y., N. H. & H. R. R.:		
(1) Power-house (27,500 KW.) (Based on average peak)		$2,750,000.00
(2) Transmission lines and overhead contact system.		
13.43 miles 4-trk.@$40,000 per mile	$536,000	
52.58 miles 2-trk.@ 20,000 per mile	1,051,600	
17.71 miles 1-trk.@ 7,000 per mile	123,970	
61.14 mi. yd. trk.@ 4,000 per mile	244,560	
		1,956,130.00
(3) Suburban terminal shops and inspection facilities		435,000.00
(4) Heavy repair shops (Based on percentage of equipment)		172,000.00
(5) Electric locomotives:		
Light pass. type—48@$40,000	$1,920,000	
Heavy pass. type—21@ 45,000	945,000	
		2,865,000.00
(6) Spare parts for electric locomotives (Based on 5% of Item 5)		143,250.00
(7) Multiple-unit motor cars. 100@$30,000		3,000,000.00
(8) Multiple-unit trail cars. 116@$13,300		1,542,800.00
(9) Spare parts for m.-u. cars (Based on 2.5% of Items 7-8)		113,570.00
(10) Signaling (automatic block)		885,000.00
		$13,862,750.00
B. & M. R. R.:		
(1) Power-house (32,500 KW.) (Based on average peak)		$3,250,000.00
(2) Transmission lines and overhead contact system:		
2.03 miles 4-trk.@$40,000 per mile	$81,200	
75.49 miles 2-trk.@ 20,000 per mile	1,509,800	
14.75 miles 1-trk.@ 7,000 per mile	103,110	
50.06 miles yd.trk.@ 4,000 per mile	200,000	
		1,894,110.00
(3) Suburban terminal shops and inspection facilities		982,000.00
(4) Heavy repair shops (based on percentage of equipment)		228,000.00
(5) Electric locomotives:		
Light pass. type, 65@$40,000	$2,600,000	
Heavy pass. type, 28@ 45,000	1,260,000	
		3,860,000.00
(6) Spare parts for electric locomotives: (Based on 5% of Item 5)		193,000.00
(7) Multiple-unit motor cars: 132@$30,000		3,960,000.00
(8) Multiple-unit trail cars: 261@$13,300		3,471,300.00
(9) Spare parts for m.-u. cars: (Based on 2½% Items 7-8)		185,782.00
(10) Signaling (automatic block)		865,000.00
		$18,889,192.00

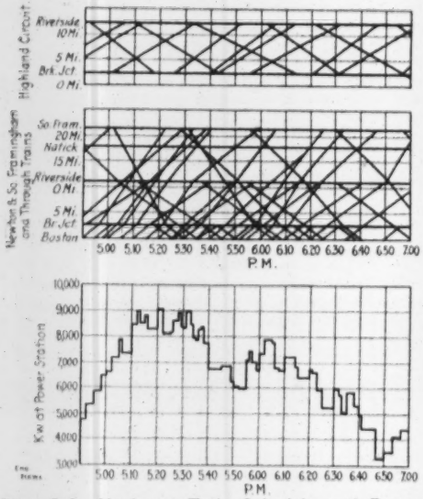
SUMMATED COSTS FOR B. & M. AND N. Y., N. H. & H. R. R.

(1) Power house	$6,000,000.00
(2) Transmission lines and overhead contact system	3,850,000.00
(3) Suburban terminal shops and inspection facilities	1,417,000.00
(4) Heavy repair shops	400,000.00
(5) Electric locomotives	6,725,000.00
(6) Spare parts for electric locomotives	336,250.00
(7) Multiple-unit motor cars	6,960,000.00
(8) Multiple-unit trail cars	5,014,100.00
(9) Spare parts for multiple-unit cars	299,352.00
(10) Signaling	1,750,000.00
	$32,751,942.00

cated near the South Station, near Riverside and near Natick, respectively. The power station would contain three 7,500-KW. turbo-generators, producing current at 11,000 volts, three-phase, 25-cycles. Substations 1 and 2 will contain three 1,500-KW. rotary converters and No. 3 three 750-KW. rotary converters. Figs. 5 and 6 show the power required to operate the existing schedule, and the schedule which would be possible with the above power installation.

In considering a radical change of this character and its consequent large investment, it is indispensable that some provision be made in the original plan to permit of a reasonable assumed expansion in business to avoid a wasteful reconstruction or revision of the plant to meet such a contingency. It is believed that the assumed increase in the schedule is conservative.

It has been assumed that aerial transmission lines for both high and low tension will be used on the main line from St. Mary's St. to Natick, and the high-tension feed-



Figs. 5-6. Maximum Train Schedule and Power-House Load Diagram for the Present Express and Suburban Service of the Boston & Albany R. R., at Boston.

ers of St. Mary's St. will be insulated cables, either fixed in the ground or attached to the walls of the track depression. No high-tension lines will be required upon the Highland Circuit.

The working conductor assumed is the under-running, protected, third-rail, similar to that now employed by the New York Central & Hudson River R. R. in New York City, using 1,200-volt direct current instead of 600, as heretofore employed, this higher voltage being a more recent development of the art, and more economical than the former practice.

TRAIN EQUIPMENT.—It has been assumed that the Circuit trains and the Boston-South Framingham trains would consist of multiple-unit motor cars, and that the through trains would be handled between South Framingham and Boston by electric locomotives, substantially similar to those now used by the New York Central in New York City.

The present service will require the following new equipment: 16 electric locomotives; 62 motor cars; 31 trailer cars. This new equipment would retire substantially 29 steam locomotives and 113 passenger coaches.

SIGNAL SYSTEM.—The present signal system is now controlled by direct currents in the track rails. In the adoption of electricity as a means of propulsion it is necessary to substitute alternating currents for signal control, which requires a complete rearrangement and reconstruction of the existing signal system, which, for the district under consideration, will cost approximately $700,000.

TIDAL BASIN.—Certain portions of the track between the South Station and Boylston St. are now occasionally submerged during high tides or violent storms. It will be necessary to eliminate this trouble by larger tidal basins and drainage systems before electrification is undertaken, which work will cost approximately $60,000.

COSTS.—The estimated costs of the above work and the annual expense resulting therefrom are summarized substantially as follows:

	Cost.	Annual expenses.
Cost of construction.....	$7,520,300	$1,172,604
Credit	1,107,000	633,413
Increase, net.....	$6,413,300	$539,191

Owing to the limited time at our disposal for the investigation of the matter, this statement must necessarily be regarded as a rough approximation. However, it is believed to be conservative, and should such work be undertaken it is probable that the final cost would be more than here stated.

REVENUES.—The gross revenue derived by the Boston & Albany R. R. and in the district under consideration, including return tickets, single-trip tickets, mileage proportion for traffic entering and leaving Boston for points west of South Framingham, is approximately $1,300,000.

The visible operating expenses of affording this service under steam operation at the present time, without any interest whatever upon the large investment for right-of-way, tracks and structures, is slightly in excess of the gross receipts.

If to this present deficit there be added the above additional annual expense as result of electrification, namely, $539,191, the net revenue above operating expenses which accrues to the Boston & Albany R. R., as a whole, from the business handled in and out of the city of Boston between all points on the road will be practically absorbed, thus leaving no net revenue from such service to meet existing obligations or those which would be created by this new investment.

The solvency of a transportation company is of paramount importance to the public as well as to the railroad. Insolvency necessarily means inefficient service, and inefficient service means inconvenience and commercial and industrial calamity to the public.

It would therefore seem imperative that any Act providing for the electrification of steam railroads under such circumstances empowering the proper board or boards to determine the manner in which such work should be prosecuted, should also empower the Board or other properly constituted authorities to permit the railroad companies to assess all passengers and traffic, using the facilities, with a terminal charge sufficient to bear the financial burdens imposed, with some additional profit to the operating company for performing the service and assuming the additional responsibilities and liabilities necessarily introduced.

This would seem more consistent and equitable than to impose it upon other cities, villages or rural communities in local fares or other forms of transportation which receive no real estate or other benefits from the new form of transportation employed.

The Boston & Albany R. R. has no material source of income except the receipts from transportation afforded the public. If the public elects through legislative mandate to have that service provided through the use of more costly appliances and methods than formerly, the conclusion is inevitable that the public must ultimately pay the cost and should therefore have full information on the subject in advance. The case is analagous to the elimination of grade crossings, where the public participates in the immediate costs and assumes in transportation expenses the carrying charges on the remainder.

OPERATION.—The art of electric traction has advanced to the extent that 1,200-volt working conductors are now considered permissable, instead of the 600-volt formerly employed. This advance in the art appreciably reduces the cost of future substation construction, and studies are constantly in progress by many railroad companies, manufacturing companies and engineers, to devise further systems and economies which may render the electrification of steam railroads in congested centers a financial possibility, without undue burdens upon the public.

Meanwhile, the Boston & Albany R. R., acting in good faith under its promises to the Railroad Commission to make efforts to abate the nuisance concerning which complaint had been made, has spent about a third of a million dollars in equipping the suburban lines in the vicinity of Boston with powerful modern suburban locomotives in order that their work while handling trains might be less laborious. This reduces the need for rapid stoking of the engines, and gives the fireman a wider latitude in which to replenish his fires, and greatly reduces the smoke and noise nuisances. We have also been endeavoring to keep these locomotives supplied with a high grade of low-volatile coal, in order that the source of the trouble might be further reduced. Efforts to improve the situation will be continued.

Yours respectfully,
(Signed) A. H. Smith,
Vice-President and General Manager.

Opening of the Michigan Central Ry. Tunnel Under the Detroit River.

The Detroit River tunnel of the Michigan Central Ry., between Detroit, Mich., and Windsor, Ont., has been put into service for regular railway traffic without any formalities or ceremony. On Sept. 18 the railway company began running regular freight trains through the tunnel, and the traffic was increased gradually until on Oct. 16 all trains were using the tunnel and the car-ferry steamers were laid up. We are informed that the work is entirely satisfactory. The tunnel is quite dry, and its ventilation good. The electrical equipment also is satisfactory and there has been no trouble in operating 70-car freight trains.

The tunnel is specially notable for the novel and bold method adopted for the construction of its river section at a high level, so as to avoid excessively long approaches for a deep-level tunnel. The river section is composed of series of 11 twin-tube steel shells which were built on shore, towed to the site and sunk by water ballast to seats in a trench dredged in the river bed. As this work was done in deep water and a swift current the difficulties were many. When in place, the shells were surrounded completely by concrete deposited under water by pipes. The tubes were then pumped out and given a concrete lining. The work has been described very fully in our issues of Feb. 15, 1906; Oct. 31, 1907, and Sept. 24, 1908. The total length of the river section is about 2,620 ft., and the total length of electrically operated line is about six miles. The approaches are twin-tube concrete tunnels extending to the double-track open cuts which rise to the surface. The approaches have grades of 2%.

The trains are hauled by double-truck electric locomotives of the 0-4-4-0 class. Two of these (operated as one machine) are used for the heavy trains, being designed to handle 1,800-ton trains up the approach grades at 10 m. p. h. Each engine has a weight of about 100 tons on its eight 48-in. driving wheels. Power is furnished by the Detroit Edison Co. and delivered to a substation whence 650-volt direct-current is delivered to the third-rail conductor. The substation furnishes current also for the electric lighting of the tunnel and approaches and for drainage pumps. The electrical equipment was described in our issues of May 23, 1907, and June 24 and July 1, 1909.

The work was done for the Detroit River Tunnel Co., an auxiliary of the Michigan Central Ry. Mr. W. S. Kinnear, M. Am. Soc. C. E., was Chief Engineer and Manager; Mr. Benjamin Douglas, M. Am. Soc. C. E., was Tunnel Engineer. The contract for the entire work was taken by the Butler Bros. & Hoff Co. The locomotives were built jointly by the General Electric Co. and the American Locomotive Co.

Notes from Engineering Schools.

UNIVERSITY OF WASHINGTON.—Additions have been made to the laboratories here to permit the complete examination of the most important road materials. A road-materials laboratory for testing road "metal" and paving materials has been equipped and placed under the administration of the Department of Civil Engineering. A laboratory of industrial chemistry has been fitted out for the analysis of bitumen and other binders.

The work of the road-materials laboratory will be largely in the examination and testing of "metal" for macadam and similar roadways. It is proposed to cooperate with road builders throughout the state in determining (1) which of several available materials is the most suitable for a given purpose, (2) whether it is economical to bring a material from a distance rather than to use a local one, (3) to establish standards by the comparison of service results with laboratory examination. This laboratory is equipped for making specific gravity, water-absorption, abrasion, hardness, toughness and cementing tests. All this equipment conforms to that adopted by the U. S. Office of Public Roads. It is proposed wherever possible to make tests on rock for the state and for counties and towns without charge. For private parties a moderate fee is proposed. This laboratory work will be under the immediate supervision of Mr. Julius Adler, Instructor in Civil Engineering, and under the general direction of Prof. A. H. Fuller, Dean of the Engineering College. The work done will be a part of the regular course in highway engineering.

The laboratory of industrial chemistry has been equipped for testing all kinds of bituminous binders for roads. While the suitability of a binder cannot yet be fully determined by laboratory tests, it is proposed to develop regular

work in recognition tests and to establish if possible a relation between the laboratory results and actual use. The proposed schedule of tests includes those for specific gravity, per cent of fixed bitumen and of free carbon, penetration viscosity and consistency for both tars and asphalts, flash point and volatization loss of asphalts, and for the destructive distillation of coal. This laboratory is in charge of Prof. H. S. Benson of the Chemistry Department, assisted by Mr. Julius Adler. A series of lectures will also be offered for civil engineering students on the composition and properties of road-binding materials.

THE STEAMER "KAISER WILHELM DER GROSSE" of the North German Lloyd line lost her port propeller at sea Dec. 5 while several hundred miles east of Sandy Hook bound for New York. She proceeded at a reduced speed of about 15 knots, running with her starboard engine alone, and reached her dock safely Dec. 7.

IN RECENT AEROPLANE ACCIDENTS three aviators have been killed. An amateur named Walter Archer rose to a height of 700 ft. at Salida, Colo., on Dec. 3, in a home made machine driven by an electric motor. It is reported that power was received through a feed wire attached to local service mains and that when the end of the wire was reached the connections were broken, depriving the motor of power and causing it to fall.

At Centocelle, near Rome, Italy, on Dec. 3, Lieut. Cammarota, of the Italian Army Engineer Corps, and a private, fell with a Farman biplane flyer from a height of 80 ft. and were killed. It is reported the machine capsized in making a short turn.

THE LAKES-TO-THE-GULF WATERWAY CONVENTION held recently at St. Louis is commented upon by the Chicago "Tribune" as follows:

> The lakes-to-the-gulf deep waterway association has outlived its usefulness. Organized to promote a work for the public welfare, it has degenerated into a scramble for private benefit at the expense of the public. The cheapest kind of partisan politics was attempted at the late convention. The association should either mend its ways or not meet again.

CONCRETE BLOCKS CAST WET IN SAND MOLDS have greater strength and density than when pounded or pressed dry in non-absorptive molds, according to an account of tests in "The Sibley Journal of Engineering," November, 1910, by Prof. R. C. Carpenter, of Cornell University. In making the tests four kinds of molds were used, as follows: (1) Sand molds such as are used in iron foundries; made in flasks and surrounded by about 4 ins. of sand; highly absorptive; (2) molds of mortar which had set before concrete was poured, relatively non-absorptive; (3) wooden and plaster of Paris molds; practically non-absorptive. In these three sets of molds the concrete mix was poured wet and allowed to set without ramming or tamping. Finally a fourth set of molds of wood were used into which a dry concrete was rammed hard, after the manner usually employed in concrete block manufacture. In all mixes a proportion of one cement to six of crushed marble aggregate, ¼-in. and less in size, was used.

At the end of 86 days (except in the three blocks noted) the blocks, all practically 3-in. cubes, were tested for compression strength with the following results:

	Crushing lbs. per sq. in.
Poured liquid in absorptive sand molds....	2,475
	2,530
	2,472*
	2,680*
	2,675*
Poured liquid in approximately non-absorptive molds	1,680
	1,592
	1,690
Poured in non-absorptive wooden molds.....	1,310
	1,333
Poured in plaster of Paris molds.....	1,905
	1,868
	1,707
	1,682
Rammed dry in wooden molds.....	617
	480
	538

*180 days old; all the rest were 86 days old.

On some other blocks of larger size, a limited number of tests showed that the percentage of absorption of moisture was lower in those blocks poured in a sand mold than in those either poured or rammed in a non-absorptive mold.

It should be noted that the tests were few in number and that the blocks were much smaller than those ordinarily used in practice.

RAILWAY AND CANAL APPRAISAL in New Jersey for taxation purposes has been carried on under special legislative enactment during the past year. Mr. Charles Hansel, M. Am. Soc. C. E., is in charge of the work, with office in Elizabeth, N. J. His field force has comprised as many as 50 to 60 field men and the office force about 20, a total organization of nearly 80. The canal portion of the work is of minor importance. The railway trackage of the State includes 2,365 miles of main track, and 4,400 total miles of track. There are 121 railway corporations concerned. The field work comprised complete surveys and quantity estimates of roadbed, structures, equipment, shops, ferry-boats, etc.; this work is now practically finished. Records of values of land adjoining railway rights-of-way were compiled, from local assessment records, which figures will be taken into account in placing a value on the railway lands. The final report of the appraisal will be presented to the coming legislature.

REBUILDING STREET RAILWAY TRACKS in narrow crowded streets was one of the problems incidental to the reconstruction of the Chicago street railways, as described in our issue of Nov. 3. In wide streets a third temporary track was laid, but in some of the narrow streets in the business district this was impracticable. In some of these streets, with a traffic of cars and other vehicles the work was actually done without interrupting traffic, except that one side of the street at a time was closed to street vehicles for a length of one or two blocks. One track was handled at a time, and in the short intervals between cars the paving was removed, the earth excavated to new grade between the ties, new ties placed, and electric conduits laid in a trench in the middle of the new grade. During the periods of lighter traffic, the new rails were laid, the new ties being blocked up to the proper elevation. Broken stone ballast was then filled and tamped, and covered with stone screenings to fill the voids, the screenings being well watered from a hose. Then the paving was laid, openings being left at the rail joints and the electric welding of the joints being done at night. By working in this way there was no interference with the traffic of cars of important routes, and it was surprising to see how fast the work progressed under such adverse conditions.

AN EXHIBITION OF MARINE OIL ENGINES was opened at Great Yarmouth, England, Oct. 29. The object has been to secure a representative collection of heavy oil engines suitable for the propulsion of herring drifters. Seven engines are shown in operation, five of which are provided with propellers immersed in tanks. The following notes on the engines exhibited are from the London "Times" Engineering Supplement of Nov. 2:

The Blackstone crude-oil engine has four cylinders developing 80 B. HP. at 450 r. p. m. The ignition consists of a hot bulb into which an oil spray is injected by compressed air. The bulb is kept hot even when the engine is running light. Reversing is effected by sliding a set of reversing cams into gear.

A Norris & Henty three-cylinder, paraffine-oil engine develops 60 B. HP. at 500 r. p. m. A shaft governor exercises a final control on the hit-and-miss principle, preventing excessive speeds when the propeller is out of water. The vaporizers are heated by lamps when the engine is working or is apt to be needed.

A Griffin four-cylinder crude-oil engine is shown with a special vaporizer for tar recovery. It is started by means of the stored energy in a free fly-wheel.

A Dromhout two-cylinder engine, made by Perman & Co., develops 56 B. HP. at 285 r. p. m. This engine is started with gasoline.

A Thornycroft four-cylinder, paraffine-oil engine develops 47 B. HP. at 500 r. p. m. Only one vaporizer is used, which has to be heated by a lamp for starting, although sufficient heat is retained for restarting after a stoppage of up to about an hour. Ignition is by high-tension electric current and the oil for lubrication is pumped to a series of nozzles which deliver visibly into cups leading to various points.

AUTOMATIC BLOCK SIGNALS FOR ELECTRIC railways are likely to come into somewhat extended use as a result of the agitation following a series of unusually disastrous collisions. The Illinois Traction System, with over 500 miles of line, has placed an order for signal equipment for certain stretches of line aggregating about 100 miles. Passing sidings will have home and distant signals for both directions, the distant signals (about 1,800 ft. from the home signals) greatly facilitating the handling of the traffic. The signals will not clear until the switch is properly set, with the point rail in close contact with the switch rail. The signals will be placed also at long curves on high-speed lines, at the ends of double-track sections, and in stretches of single-track of 5 to 20 miles in length. Current at 2,300 volts will be distributed from the substations over copper wires and reduced by transformers to 110 volts for the signal apparatus and lamps and 12 volts for the track circuits. The signals will be of the semaphore type of the Union Switch & Signal Co. In addition to these automatic block signals, the company will equip about 100 miles of its lines with the train-order signals of the Baird Electric Co. These are operated by the train dispatcher, and may be displayed when trains (or cars) are required to stop at any point for special orders.

SOLID ROLLED BOILER DRUMS.—The London "Times" Engineering Supplement of Nov. 2 states that the two torpedo-boat destroyers recently ordered by the British Admiralty from Messrs. Yarrow & Co. are to be equipped with water-tube boilers having seamless steam drums and rolled to the requisite diameter from the solid bloom. The rolling of the first of the steel drums has recently been successfully done in the Sheffield Works of John Brown & Co., Ltd. The mill employed is of a special character, worked out for the manufacture of turbine rotor drums up to 12½ ft. in diameter. The boiler drums noted are 11 ft. 6 ins. long by 5 ft. internal diameter, and 1-9/16 ins. thick. This thickness is required at the tube holes, but elsewhere over the circumference the drum is placed down to the thickness required for strength to resist pressure, etc. The seamless drum is much lighter for a given strength over the riveted one, and it is believed that this advantage is of sufficient importance to justify the extra expense.

WIRELESS TELEGRAPH STATIONS have been cataloged by the Bureau of Steam Engineering of the U. S. Navy. There are shown to be 1,520 wireless stations on land and ships all over the world, not including foreign warships and amateurs' installations. Of these, 700 are on land, 88 being on the American Atlantic and Gulf coasts, 48 on the Great Lakes, 51 on the Pacific coast, 16 in Alaska, and three in the interior. The United States Navy has 47 of these shore stations and 344 ships equipped. The U. S. Army has 30 land stations and 16 vessels equipped. In the list of merchant vessels, 821 equipments are noted.

SOLID ROCK EXCAVATION BY STEAM SHOVEL has been successfully accomplished by a contractor in Danville, Ill. The shovel is a Vulcan Giant, Class B, weighing 120 tons and with a one and one-half cubic yard dipper. The excavation is made in solid shale rock of a bluish color, as hard as limestone, and known as kidney rock. It is not blasted and cannot be shaved off like ordinary rock shale, but is broken off in small chunks by the dipper teeth. It is used by the Danville Brick Co. in the manufacture of paving bricks. The shovel requires three men to operate, an engineer, a craneman and a fireman. The coal consumption is about two tons a day. This method of handling the rock eliminates not only the expense of blasting, but also the use of a crusher, for the material is excavated sufficiently fine for use in the grinders. These facts are taken from "Steam Shovel News" for November, 1910.

BOILER SCALE in electric transformer cooling coils is noted in the "Electrical World," Dec. 1. Artesian well water was used for transformer cooling coils in a substation of the Minneapolis General Electric Co. For a year trouble was encountered with excessive temperature rise of some of the transformers and finally it was discovered that the water pipes were clogged with a hard deposit which not only reduced the flow of water but also prevented the absorption of heat. The coils were cleaned by running through a 10% solution of acetic acid and a water-treating plant was ordered having a capacity of 1,000 gals. per day. The cooling water on analysis showed a total of 49 parts of solids in 10,000, the principal substances being calcium and magnesium carbonates (32.9 parts), sodium chloride (6.9), calcium sulphate (3.4), silica (2.2).

AN EXTRAORDINARY HYDRAULIC DREDGE RECord was made during the month of October by the dredge "Champlain," working on Contract No. 25, just north of Dunhams Basin on the Champlain branch of the New York State Barge Canal. During the month, in an actual working time of 565 hrs. and 35 mins., this dredge took out 500,352 cu. yds. of material from the canal prism, an hourly average of 885 cu. yds. The former dredging record on the Barge Canal was made by a machine on the Montezuma marshes during September, 1909, when 454,706 cu. yds. were taken out. In each case the material was much easier for excavation than the average through the Canal, and conditions were generally favorable. The "Champlain" is a 20-in. suction dredge, with an A-frame forward supporting the cutter head which works against the vertical face of the cut, and having a discharge pipe also of 20-in. size.

Personals.

Mr. E. J. Snell has been appointed Master Mechanic of the New York Central & Hudson River R. R. at Corning, N. Y.

Mr. W. K. Vanderbilt, Jr. has been elected Vice-President of the New York & Harlem R. R., a subsidiary company of the New York Central Lines.

Mr. James Berlingett, General Manager of the St. Joseph & Grand Island Ry., has been appointed Assistant General Manager of the Virginia Ry., with headquarters at Norfolk, Va.

Mr. Willard Kells, formerly Master Mechanic of the Lehigh Valley R. R. at Buffalo, N. Y., has been ap-

pointed Assistant Superintendent of Motive Power of the Atlantic Coast Line R. R.

Mr. C. W. Raynor, Assoc. M. Am. Soc. C. E., has resigned his position as Chief Engineer of the C. G. Sheely Contracting Co., of Denver, Colo, to accept a similar position with the Coast Bridge Co., of Portland, Ore.

Mr. Wills Maclachlan, Assoc. Am. Inst. E. E., Construction Engineer for the Canadian Westinghouse Co., of Montreal, Que., has been appointed Electrical Engineer for the city of London, England. Mr. Maclachlan is a graduate of Toronto University, class of 1906, and was for some time with Westinghouse Electric & Manufacturing Co., of Pittsburg, Pa.

Mr. E. N. Lake, M. Am. Soc. C. E., formerly Division Engineer with the Board of Supervising Engineers of Chicago, Ill., in charge of the electrical transmission and distribution work in the construction of the street railways, has accepted a position with the Stone & Webster Engineering Corporation, of Boston, Mass.

Mr. C. F. Loweth, M. Am. Soc. C. E., Engineer and Superintendent of Bridges and Buildings of the Chicago, Milwaukee & St. Paul Ry., has been appointed Chief Engineer, succeeding Mr. D. J. Whittemore, M. Am. Soc. C. E., who has resigned after 57 years of continuous service, for 47 years of which he has been Chief Engineer. Mr. Whittemore continues his connection with the company as Honorary Consulting Engineer.

The citizens committee of prominent business men, to represent the Chamber of Commerce and the Merchants' Association of New York City at the subway conferences suggested by Mayor Gaynor, includes among its 30 members the following engineers: Messrs. Irving T. Bush, Alfred P. Boller, M. Am. Soc. C. E.; William H. McCord, Samuel Rea, M. Am. Soc. C. E.; Franklin Remington, Charles Sooysmith, M. Am. Soc. C. E., and William J. Wilgus, M. Am. Soc. C. E.

Mr. George Warrington, of Chicago, Ill., has been appointed Superintendent of Naval Construction of the U. S. Bureau of Light Houses, of which Mr. G. R. Putnam is Commissioner. The appointment of Mr. Warrington completes the executive staff of this bureau. It is the intention of the bureau to hold civil service examinations in the near future for both engineering positions in connection with light-house construction and nautical positions in connection with the operation of light-house vessels. The other appointments to the executive staff, Mr. Arthur V. Conover, Deputy Commissioner, and Mr. John S. Conway, Chief Constructing Engineer, were noted in these columns some weeks ago.

Obituary.

Charles William Clinton, Fellow of the Am. Inst. of Architects, died on Dec. 1 at his home in New York City. For many years he was one of the most prominent architects of the city. Among the buildings of which he was architect are the Mutual Life Insurance Building, the Seventh Regiment Armory, the Hudson Terminal Buildings and the Hotel Astor.

Matthew Henry Buckham, D. D., President of the University of Vermont for 39 years, died at his home in Burlington, Vt., on Nov. 22. He was born of Scotch ancestry in Hinckley, Leicestershire, England, on July 4, 1832. His parents removed to this country during his infancy. He entered the University of Vermont as a student at the age of 15 years. He served for some years as a Professor in the University, and was elected President in 1871, succeeding President Angell, who retired from the Presidency to go to the University of Michigan.

James O. Clephane, of Englewood, N. J., died on Nov. 30, at the age of 68 years. Although a lawyer by profession he was prominently identified with the development of the typewriter and the linotype type-setting machines. It is said that under his direction the first Remington typewriter was built, and that he suggested to Mergenthaler the idea of a type-setting machine, the result of which was the Mergenthaler linotype machine. Mr. Clephane was more recently connected with the development of the graphophone as the organizer of the American Graphophone Co.

Jonathan Dwight, a civil engineer and contractor of New York City, died on Nov. 21 at the age of 80 years. For many years he was a prominent contractor on railroad construction in New England, especially on the lines of the New York, New Haven & Hartford R. R. and the old New York & New England R. R. He was a descendant of an old New England family of Springfield, Mass., where he was born. He graduated from Harvard in 1852 and immediately took up engineering work. He was at one time connected with the engineering department of the New York Central & Hudson River R. R.

William H. Bryan, M. Am. Soc. M. E., died very suddenly at Chicago on Dec. 7. Mr. Bryan for some years has been practicing in St. Louis, but on Nov. 28 went to Chicago to take the position of Chief Engineer of the Board of Education of that city. He was to have had charge of all the mechanical equipments of the various schools, with supervision of their heating, lighting, power and water supply plants, etc. Mr. Bryan obtained this position as the result of a civil service examination.

Engineering Societies.

COMING MEETINGS.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS.
Dec. 12-14. Annual convention at New York City. Secy., Percy H. Wilson, Land Title Bldg., Philadelphia, Pa.

NATIONAL ASSOCIATION OF CEMENT USERS.
Dec. 12-17. Annual convention at New York City. President, Richard L. Humphrey, Harrison Bldg., Philadelphia.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
Dec. 27. Annual meeting at St. Paul, Minn. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS.
Dec. 27-28. Annual meeting at Lafayette, Ind. Secy., E. W. Hamilton, Iowa State College, Ames, Iowa.

CANADIAN SOCIETY OF CIVIL ENGINEERS.
Jan. 2-6. Annual meeting at Winnipeg, Man. Secy., C. H. McLeod, 413 West Dorchester St., Montreal, Que.

INDIANA ENGINEERING SOCIETY.
Jan. 12-14. Annual meeting at Indianapolis, Ind. Secy., Charles Brossmann, Indianapolis, Ind.

MONTANA SOCIETY OF ENGINEERS.
Jan. 12-14. Annual meeting at Helena, Mont. Secy., Clinton H. Moore, Leyson Block, Butte, Mont.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.
Jan. 17. Annual meeting at Pittsburg, Pa. Secy., Elmer K. Hiles, 803 Fulton Bldg., Pittsburg, Pa.

AMERICAN INSTITUTE OF ARCHITECTS.
Jan. 17-19. Annual convention at San Francisco, Cal. Secy., Glenn Brown, the Octagon, Washington, D. C.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
Jan. 18-19. Annual meeting at New York City. Secy., Charles Warren Hunt, 220 West 57th St., New York City.

ILLUMINATING ENGINEERING SOCIETY.
Jan. 20. Annual meeting at New York City. Secy., P. S. Millar, 29 West 39th St., New York City.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.
Jan. 24-26. Annual meeting at New York City. Secy., W. M. Mackay, P. O. Box 1818, New York City.

OHIO ENGINEERING SOCIETY.
Jan. 24-26. Annual meeting at Columbus, Ohio. Secy., C. J. Knisely, New Philadelphia, Ohio.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.
Jan. 25-27. Annual meeting at East St. Louis, Ill. Secy., E. E. R. Tratman, 1636 Monadnock Block, Chicago, Ill.

NATIONAL BRICK MANUFACTURERS' ASSOCIATION.
Feb. 6-11. Annual convention at Louisville, Ky. Secy., T. A. Randall, Indianapolis, Ind.

BROOKLYN ENGINEERS' CLUB.—The annual dinner will be held Dec. 13. Addresses will be made by Dr. Alex. C. Humphreys, Mr. John F. O'Rourke, Mr. Wm. G. McAdoo and Dr. Rossiter W. Raymond.

INSTITUTION OF ELECTRICAL ENGINEERS.—The first meeting of the Institution in its own building, Victoria Embankment, London, was held in November. The Institution has relied heretofore on the hospitality of the Institution of Civil Engineers and the Royal Society of Arts whenever a large attendance had to be provided for. The Council of the Institute recently took over the building of the Royal College of Physicians and Surgeons and reconstructed the interior.

NEW ENGLAND WATER WORKS ASSOCIATION.—An excursion to the Chestnut Hill pumping station of the Metropolitan Water Works will be a feature of the regular meeting of Dec. 14 at Boston, Mass. Papers will be presented as follows: "Water Filtration Plant at Newport, R. I.," Robt. E. Milligan, Manager of the N. Y. Continental-Jewel Filtration Co.; "Some Difficulties in the Purification of Water Supplies," Gardner T. Swarts, Secretary, State Board of Health of Rhode Island; "The Panama Canal," Lewis K. Rourke, Superintendent of Streets, Boston, Mass.

AMERICAN SOCIETY OF NAVAL ENGINEERS.—Nominations for officers for the coming year have been made as follows: For president, Engineer-in-Chief H. I. Cone, U. S. N.; for secretary-treasurer, Lieut.-Commander U. T. Holmes, U. S. N., and Lieut.-Commander John Halligan, U. S. N.; for members of council, Rear-Admiral Geo. W. Baird, U. S. N., retired; Engineer-in-Chief C. A. McAllister, U. S. R. C. S.; Capt. R. S. Griffin, U. S. N.; Commanders C. W. Dyson, W. S. Smith and Emil Theiss, U. S. N., and Commander W. W. White, U. S. N., retired. The result of the vote on these nominations will be announced at the annual meeting in Washington, D. C., Dec. 30.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.—The annual meeting of the society began in the Engineering Societies' Building, in New York City, on Tuesday evening, Dec. 6. A report was presented by the tellers of election, giving the results of the letter ballot for election of officers for the ensuing year. Col. E. D. Meier, of New York City, was elected President, and the following were chosen as Vice-Presidents: Messrs. H. H. Vaughan, of Montreal; E. M. Herr, of Pittsburg, and Geo. M. Brill, of Chicago; for Managers, were elected Messrs. D. F. Crawford, of Pittsburg; E. B. Katte, of New York City, and Stanley G. Flagg, of Philadelphia; and for Treasurer, Hon. Wm. H. Wiley, of New York City. Mr. Geo. Westinghouse, Retiring President of the Society, delivered the annual Presidential address, taking as his subject "The Development of the Air Brake." A reception by the President and President-elect and their ladies followed.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS.—During the cement show in New York City, lectures will be given in Madison Square Garden Concert Hall, Dec. 15-20, at 3 p. m. and 8.30 p. m., except Thursday and Friday evening and Sunday. The following lectures will be given: "Transportation Terminals," Calvin Tomkins, Commissioner of Docks and Ferries of New York City; "Fireproofing Materials," Rudolph P. Miller, Commissioner of Buildings, New York City; "The Largest Commercial Building in the World," J. Hollis Wells; "Large Reinforced-Concrete Bridges," E. P. Goodrich, Consulting Engineer, New York City; "The Part Played by Concrete in Rural Highways," Logan Waller Page, Director of Public Roads, U. S. Department of Agriculture; "The Age of Cement Structure in the German tongue), Charles Wisch, formerly Chief Municipal Architect, Cologne, Germany.

AMERICAN ECONOMIC ASSOCIATION.—The preliminary announcement of the 23rd annual meeting at St. Louis, Mo., Dec. 27-30, presents the following program:

Dec. 27. Joint session with the American Political Science Association. Dec. 28. Sessions on money and prices, economic theory (the Ricardo centenary), and accountancy. Dec. 29. Sessions on canals and railways, the problem of immigration and industrial legislation: Papers on canals and railways will be read by Prof. Emery R. Johnson, University of Pennsylvania, Hon. J. Hampton Moore, Philadelphia, and Prof. E. R. Dewsnup, University of Illinois. At the session on industrial legislation, which will be a joint session with the American Association for Labor Legislation, papers will be read on "Industrial Accidents and Diseases," "Lead Poisoning in Illinois," "Industrial Diseases in America," "Voluntary Indemnity for Injured Workmen," "Compulsory Compensation for Injured Workmen" and "Progress and Next Steps in Workmen's Compensation." Dec. 30. Session on taxation and monopolies.

GENERAL CONTRACTORS' ASSOCIATION.—The annual dinner of this Association was held, Dec. 1, at the Knickerbocker Hotel, New York City, and was attended by about 200 well known engineers and contractors. Mr. Charles A. Angell, President of the Association, acted as toast-master, and the after-dinner speakers included Mr. John R. MacArthur, Hon. John A. Bensel, State Engineer-elect, of New York; Rear-Admiral R. C. Hollyday, Chief of the Bureau of Yards and Docks, U. S. Navy; Hon. William A. Prendergast, Comptroller of New York City; Hon. John Williams, Chief of the New York State Bureau of Labor, and Hon. Cyrus C. Miller, President of the Borough of The Bronx. The report of the Treasurer showed receipts and expenditures of about $10,000 and a comfortable balance in the treasury. The report of the Secretary, Mr. C. A. Crane, reviewed the work of the Association in protecting the interests of contractors in the matter of pending legislation and ordinances in the State Legislature and in New York City and the revision and standardization of contracts and specifications in New York. The Association, which is made up of large firms of contractors having headquarters in New York City or vicinity, now has 39 active members, and a total membership of 53.

AMERICAN CHEMICAL SOCIETY.—Among the papers to be presented at the annual meeting to be held at Minneapolis, Minn., Dec. 28-31, are the following: "The Spontaneous Combustion of Coal," S. W. Parr and F. W. Kressman; "The Modern Manufacture of Portland Cement from the Chemical and Mechanical Standpoint," George P. Dieckmann; "The Utilization of Smelter Smoke in Preparing Sulphates from Clays," Harrison Everett Ashley; "The Determination of Water in Mixer Paints," G. A. Abbott; "Linseed Oil," A. H. Sabin; "A Modified Process for Cane Sugar Manufacture," Harry McCormoack; "Notes on the Production and Composition of Mexican Pulque and Mescal," H. W. Rohde; "Direct Currents in a Closed Liquid Circuit," F. C. Frary and J. B. Bolton; "Electrical Equipment for Electroanalysis and Electric Furnace Work," F. C. Frary; "Chemical Properties of Certain Radioactive Substances," B. B. Boltwood; "Radioactivity of Thorium Products," Herbert N. McCoy; "The Vapor Pressures of Sulphur," Allan W. C. Menzies; "A Lower Limit for the Critical Temperature of Mercury," Allen W. C. Menzies; "The Diffusion of Oxygen through Solids," G. B. Frankforter and R. S. Callaway; "Snow as a Means of Studying the Smoke Nuisance," G. B. Frankforter; "The Hydrocarbons in the Various Forms of Lignite," G. B. Frankforter and Andrew P. Peterson; "A New Hydrogen Sulphide Generator," J. I. D. Hinds; "Electric Osmose," Harry N. Holmes; "The Rapid Determination of Silver and Cadmium by Means of the Gauze Cathode and Stationary Anode," R. C. Benner and W. H. Ross; "The Rapid Deposition of Cobalt and Nickel by Means of Gauze Cathode and Stationary Anode," R. C. Benner and W. H. Ross; "The Effect of Continued Grinding on Water of Crystallization," Nicholas Knight; "The Tendency of Chemical Energy Conversion," J. E. Siebel; "The Dielectric Capacity of Some Liquid Hydrides," R. C. Palmer and Herman Schlundt.